Antagonistic muscular co-contraction (AMCC) in piano pedagogy: An assessment of accuracy, consistency, insight, and terminology

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List of pedagogical excerpts and codes (listed per-model category)

Assessment of model findings: Characteristics of AMCC

AMCC is prevalent and should be ubiquitous
Justified agreement
Matt14_17: Interestingly, Matthay momentarily softens his dogmatic opposition to AMCC, qualifying that the “opposite set of muscles” must be “practically [rather than entirely] passive”. This contradicts numerous excerpts where Matthay demands total passivity of antagonists (e.g. Matt14_20: “perfectly free from contrary…exertion”). This inconsistency might reveal an implicit awareness that some AMCC might be required for skilled playing.

Field34_39
The excerpt suggests that “all movements” should “allow” AMCC (here “flexible fixation”).

Sch36_09
Schultz suggests that AMCC (here “the stiffening of joints”) is a "necessary and inevitable accompaniment of most phases of piano-playing”, broadly agreeing with the model.

Chi46_11
Ching correctly identifies that AMCC at “transmission joints” is necessary to make “successful” and “controlled” movements.

Chi56_02
Ching observes that AMCC (here “some degree of tension”) is desirable at any joint that is “making or preventing a movement” - which extends contradictions that began in his earlier work (e.g. Chi46_03, Chi46_12, etc.)

Justified disagreement
Because no instances whatsoever of verifiably justified disagreement with our prior model were discovered in this study, the category is therefore omitted from further subsections.

Unjustified agreement
Ort29_06: Ortmann incorrectly claims that “in normal condition every muscle exerts a certain constant degree of pull…simultaneous pull on both sides”, precluding the existence of non-AMCC movements in “normal conditions” and therefore overstating the ubiquity of AMCC.

Ort29_10: Ortmann incorrectly claims that AMCC is “necessary in some degree at all joints in order for any movement to occur”, precluding the possibility of non-AMCC movements and overstating the ubiquity of AMCC.

Sch36_05
Schultz identifies antagonistic tension via muscle tone as “essential…to the very machinery of movement”, but the ubiquity of muscle tone is still debated, and movement without antagonistic muscle tone might also be possible (Enoka, 2008)

Fras11_20
Fraser inaccurately claims that AMCC “must always be present in movement…by the very nature of physiological function”.

Unjustified disagreement
- Alternating one-sided contractions instead of AMCC (whether accompanied by relaxation or not)
    - Cal03_03: Paul Souriau (French philosopher, 1852-1926) is incorrect here in claiming that muscles in complex movement work “one after the other”; this implies (among other, even more problematic implications) that AMCC does not occur in complex movement, a fairly common misunderstanding of well-known muscle activity and wholly in disagreement with our prior model of AMCC.
    - Matt08_01 Matt08_02, Matt08_03, Matt08_04, Matt08_05, Matt08_08, Matt14_02, Matt14_04, Matt14_05, Matt14_06, Matt14_08, Matt14_10, Matt14_11, Matt14_15, Matt14_16, Matt14_20, Matt14_21, Matt14_22, Matt32_04, Matt32_05, Matt32_06, Matt32_07, Matt32_10:, Matt32_14: A series of excerpts spanning three different works in which Matthay expresses his complete opposition to AMCC (“contrary exertions”, or similar).
    - Matt14_07: Here Matthay advises one-sided contraction alternating with relaxation that must occur “the very moment that Sound-emission begins”.
    - Ort29_09: Ortmann incorrectly claims that “most movements…involved…opposite muscle-groups, one of which contracted while the other relaxed”, precluding the established prevalence of movements with AMCC. The claim is also self-contradictory with Ort29_06.
    - Ort29_11: Ortmann incorrectly claims that if “rigidity is present in a joint where movement would facilitate the total action, the condition seriously interferes” - wrongly suggesting that AMCC should not occur at joints where movement occurs, which contradicts the desirability of ubiquitous AMCC.
    - Ort29_33: Here Ortmann suggests that “stimulation of one set of muscles will be accompanied by relaxation in the antagonists…the basis of coördinated movement”.
    - Ort29_40: Ortmann now claims that “all descending movements of the arm as they are actually used…on the piano” require “partial relaxation” and “partial contraction of the muscle groups that lift the arm”; this describes a free-fall with relaxation of flexors and contraction of extensors, strangely contradictory with Ortmann’s prior claims that AMCC is required for certain types of playing (e.g., Ort29_38).

- Field34_17: Fielden recommends sequentially “contracting one set of muscles, and, on relaxing them, setting up the contraction of the reciprocal set”.
- Schm35_09: Schmitz incorrectly claims that fast playing “involve[s] simultaneous…contraction of one muscle and…relaxation of its opposite”.
- Schm35_10: Schmitz makes the unsubstantiated claim that one-sided contraction is “the most constructive training for muscular development” via the “Law of Opposites”.
- Schm35_14: Schmitz falsely suggests that “articulation…trains…contract[ion] and relax[ation] to the maximum, in alternation; it also drills the antagonist muscles in the same pair to act in a complementary fashion”.
- Schm35_15: Schmitz falsely claims that “extension of the palm…demands full relaxation of the muscles of the eminence thenar and also from the hypothenar and from the palmaris longus”, arbitrarily prohibiting any AMCC involving these muscles.
- Sch36_15: Schultz arbitrarily concludes that “the fingers of the most skilled technicians…are rarely strongly fixed” during playing, here intended to mean that AMCC should not occur in the fingers - which discounts numerous benefits of AMCC that apply equally in the fingers as elsewhere.
- Chi46_03: The excerpt is flawed in several aspects. Antagonists do not only lengthen during movement if “relaxing or…in a state of complete relaxation”; this would entirely preclude all eccentric contraction and AMCC from occurring during movement. Ching incorrectly claims that this relaxation occurs “probably in all skilled movements of the piano-playing type”. This leads Ching to wrongly conclude that agonist and antagonist should behave “as a pair of reciprocally acting engines” during movement, i.e., one always relaxing while the other contracts.
- Chi46_04, Chi46_05, Chi46_08: The excerpts continue the flawed reasoning of Chi46_03. Additionally, it is counterintuitive to refer to the active, contracting muscle as the “antagonist”, and the relaxing muscle by process of elimination the ‘agonist’. The tentpole metaphor falters on the basis of the priorly flawed reasoning: the second person “on the other side” of the “tent pole” would only be able to relax and slacken (never tighten and pull) on their “guy rope”, seriously limiting their potential to help “control the movements”.
- Cov48_02: Coviello advocates for the elimination of “contrary exertions”, i.e., AMCC.
- Chi46_94: The excerpt appears to be a red herring; Ching suddenly implies no AMCC in the wrist via “no mechanical necessity for any contraction in the raising muscle of the hand”, despite the dozens of times that he has priorly acknowledged benefits of AMCC that would apply to this case too.
- Bow61_01, Bow61_02, Bow61_03, Bow61_07: Bowen advises that AMCC “should never be allowed if possible” because it “naturally causes a tug-of-war between two sets of muscles”. Instead, “one set of muscles relaxes whilst the other acts”.
- D’Ab64_03: D’Abreu incorrectly suggests that AMCC causes an undesirable state of “no co-ordination”.
- Koch67_08: Kochevitsky wrongly suggests that “usually…two [antagonistic] muscle groups do not contract simultaneously”.
- Sán81_02: Sándor incorrectly claims that “antagonistic sets of muscles” work in alternation, as “one group…works, [while] the other group…relaxes. Partial relaxation alternates with muscular activity at all times”.
- Sán81_03, Sán81_06: Sándor now wrongly advises that “simultaneous…activation of an antagonistic set of muscles…is totally

superfluous and therefore should be avoided", contradicting Sán81_02, where he suggests that AMCC simply never occurs.

- Sán81_07: Sándor contradicts himself again by claiming that "antagonistic sets of extensor and flexor muscles…work and relax alternately", returning to his earlier claim that AMCC never occurs (Sán81_02).
- Sán81_09: After contradicting both his claims about AMCC in Sán81_08, Sándor returns to his initial claim (i.e., that AMCC does not occur).
- Tay81_05: Taylor recommends a "partially relaxed fall" of the arm in most playing, precluding AMCC.
- Bru97_12, Bru97_16: Bruser advises to avoid "co-contraction" - and implies multiple misunderstandings of functional anatomy: firstly by claiming that flexors in the forearm must be active to press down a key (when intrinsic hand muscles are also capable of accomplishing this on their own), and secondly by suggesting that the co-contraction of long finger flexors and extensors (both located in the forearm) will cause the "entire forearm" to become "unnecessarily tight" - when in fact the appreciable tightness would occur in the fingers (as well as the hand and wrist).
- Wins98_05: The authors recommend "alternating relaxation and contraction" during a "constant flow of movement".
- Mark04_02: Mark wrongly claims that "a safe technique will avoid…co-contraction".
- Taub05_01, Taub05_03: The excerpt cautions against AMCC ("you can't have…antagonistic pulls"; "clearly, they can never be used at the same time", because they "pull in opposite directions").

- Alternating AMCC and relaxation

These excerpts suggest the alternation of AMCC and relaxation, a fairly common theory of AMCC that fails to account for the benefits of AMCC that persist between the playing of individual notes at the piano (in addition to multisensory effects of AMCC between notes).

- Cal03_14: The excerpt demands "an instant, concurrent, lessening of all muscular tension, so that complete relaxation of the muscles is accomplished…[o]nce the tones have been taken", adding that "a state of tension must invariably be succeeded by relaxation or revitalisation of every joint and muscle used in playing".
- Stein05_34: The excerpt advises that "[c]ontraction and relaxation…alternate with extreme rapidity…in all muscles", inaccurately implying that movement demands fluctuation between relaxation and AMCC.
- Stein05_44: Rupert claims that firm joints "must be temporary and the state of relaxation the permanent condition" - denying the value of ubiquitous AMCC and moreover contradicting himself: temporary firmness prohibits "permanent" relaxation.
- Ort29_23: Ortmann suggests that "we may expect the relaxation to parallel the contraction" of "antagonistic muscles", implying alternating AMCC and relaxation.
- Ort29_52: Ortmann falsely claims that "the experienced player, when there is no need for further tension, relaxes immediately after tone-production" (tension here equivalent to rigidity and therefore AMCC).
- Sch36_35: Schultz advises to "rela[x]" AMCC "at every possible rest-period the musical score provides".
- Chi46_49, Chi46_67, Chi46_69, Chi46_73, Chi46_75: Ching's instructive example advises to "completely rela[x]" AMCC (here "tension") "as soon after the

playing of the last chord as possible". Similarly, "considerable tension, alternating with relaxation between the playing of each chord".
    - Sán81_08: Sándor now contradicts both his earlier claims (AMCC cannot occur, and AMCC should never occur) by advising that AMCC must occur on "frequent occasions", but must be "instantaneous, not extended".

- Alternating contraction (whether one-sided or AMCC) with relaxation
    - Cort28_01: Cortot demands that "physical effort" be "followed by complete muscular relaxation", denying the value of ubiquitous AMCC.
    - Ort29_31, Ort29_32: Ortmann claims that "contraction of a muscle should not continue after the work of the original contraction has been done…sustained contraction has…no mechanical or tonal advantage", that "most movements of piano technique are rapid contractions followed by periods of relaxation", and that "contraction…should cease not later than removal of the resistance".
    - Schm35_04: Schmitz demands "complete relaxation to alternate with the periods of muscular work".
    - Schm35_12: Schmitz recommends "stimulation of the contracting muscle" simultaneously with "inhibition of the antagonist", and similarly, "contraction desired in a certain muscle and the complete relaxation of its opposite".
    - Sch36_40: Schultz wrongly claims that AMCC is not useful in lifting the arm during "slow" playing.
    - Chi46_19: Ching believes that "we shall need tension while…playing, and relaxation…before and after", wrongly implying that any antagonistic tension would need to follow the same pattern.
    - Harr53_04: Harrison advises that "each effort must be relaxed as much as possible as soon as possible, whenever possible. Relaxation is so important that we must think about it with precision- not vaguely as something perpetually desirable". While correct that relaxation is not "perpetually desirable", it is also clear that Harrison is deeply opposed to AMCC - even in a case where it seems almost inevitable to him, he makes maximal effort to avoid it.
    - Bolt54_01: Bolton claims "there must obviously be relaxation of the muscles not needed for any given exertion". The example of "the three middle fingers should not stand out stiffly while playing octaves" is problematic: it implies that extension of the "three middle fingers" is not "needed" for the "given exertion" of playing octaves - but this extension might indeed be a necessity depending on which octaves are being played, how quickly, and how loud (e.g., to avoid hitting black keys during rapid, loud white key octave scales - which imply strong finger flexions that would indirectly flex the middle three fingers into unacceptable territory due to tendinous interconnections and mechanical coupling between finger flexors; see e.g. Furuya et al., 2021a).
    - Chi56_01: Ching recommends "a condition of the greatest possible relaxation" at any joint where "no work has to be done in making or preventing a movement" - undervaluing numerous benefits of AMCC (e.g., proprioception, or force transfer).
    - Kent76_08: Kent recommends "alternative…tensing and relaxing groups of muscles".
    - Ger07_09: Mason suggests alternation of "relaxation instantaneously…[with] muscular reconstruction", or contraction.

- Full relaxation

- Stein05_07: The excerpt supports “[t]he greatest possible relaxation” as playing a “very significant role in piano technique”, implying absence of AMCC and therefore disagreeing with the model.
- Stein05_11: The excerpt advises “natural passivity…mechanically necessary relaxation”, opposing AMCC for stability and preferring passive relaxation without evidentiary support.
- Stein05_16: The excerpt advises that “in reality [piano technique] is…a matter of momentary tension and continuous relaxation” - which itself seems inconsistent (as “momentary" tension would interrupt the continuity of relaxation), and is moreover an argument in favor of relaxation over tension (including AMCC) without basis.
- Ort29_16- Ortmann here opposes “stiffness or rigidity”, which he equates with “hypo-relaxation”, judging “its eradication” to be “one of the most important [goals] in piano pedagogy”. Given Ortmann’s largely consistent, scientific usage of “stiffness” and “rigidity”, which imply AMCC, here Ortmann is diametrically opposed to AMCC - which contradicts many of his other judgments (e.g., Ort29_10).
- Schm35_07: Schmitz here recommends broad relaxation.
- Bon53_03, Bon53_05: Bonpensiere here suggests a fully “relaxed”, “limp” hand and arm.
- Chi46_65, Chi46_66, Chi46_99: Ching wrongly suggests that “complete or virtually complete relaxation is…necessary”, even “vitally necessary…”under certain conditions”, such as “slow and soft passages”, or during “a note of long value, or…a rest”. Not only is this relaxation unnecessary, it is moreover undesirable, given the benefits of AMCC that persist during these situations.
- Harr53_02: Harrison believes “there is much to be said for having the fingers relaxed, more or less bunched together as they normally are” when approaching a “chord or octave…from a distance”.

AMCC is trainable
Justified agreement
Stein05_10
The excerpt suggests that the “degree of resistance which…must be learned in the most finely shaded gradations”, implying that AMCC (which creates this resistance, e.g. by “the shorter hand muscles surrounding the wrist…[lending] the necessary stability of resistance”) is trainable over time. (“[t]he beginner is prone to stiffen all joints” [emphasis added] is an exaggeration, but does not invalidate the excerpt’s justified agreements with the model.)

Matt14_13, Matt14_15
Matthay implies the trainability of AMCC by discussing a “direct method” of learning to exercise control over it, “when we wish”, and suggesting it is “imperative[ ]that we learn to direct” this AMCC.

Field34_38
Fielden observes that AMCC (here, a “all-inclusive muscular…impulse”) can be trained “as practice goes on”, becoming “more under control”.

Chi46_22, Chi46_24
Chi46_24
Ching observes that AMCC can be “voluntarily” controlled, discussing the practical importance of this voluntary control: “obviously it is useless to know that we have too much

or too little tension at any given joint unless we can also actually decrease or increase it by any given amount".

Chi46_44, Chi46_45, Chi46_57, Chi46_60
Ching rightfully determines that despite some "automati[c]" AMCC, we must still exercise "voluntary control" over this AMCC to ensure it is of the optimal intensity, "forming the habit…voluntarily".

Chi46_50
Ching describes in detail how to train AMCC via trial and error.

Gat65_03
Gat observes that "depending on our will", we may use antagonistic contractions "of varying intensity".

Unjustified agreement
Chi46_35, Chi46_37
Ching arbitrarily concludes that one cannot achieve varied, simultaneous AMCC "at three or more different joints" until first learning to operate AMCC at "each and every…join[t] separately", but this is incorrect. The central nervous system coordinates muscle activation patterns across multiple joints simultaneously by default, making joint-by-joint learning optional (though still not without benefit) rather than mandatory.

Unjustified disagreement
Stein05_03, Stein05_04
The excerpts claim that AMCC is innate, "according to rule", "completely unconscious", and "independent of the will", wrongly implying that AMCC is not trainable.

Stein05_05
The excerpt claims that "all muscles participate…which are able to contribute anything at all" to a coordinated movement, "thoroughly unconscious to us, nonetheless with absolute correctness and reliability", incorrectly implying that muscle use (including AMCC) is automatic and not trainable.

Stein05_42
Rupert wrongly suggests that Steinhausen advocates "the attempt to relax" antagonists (he moreso advocates the opposite- that antagonists function automatically and unconsciously; see Stein05_03, Stein05_04, and Stein05_05; and, contradictorily, advocates the attempt to activate the antagonists; see Stein05_10). Rupert makes a second error by claiming that "antagonistic muscles relax quite naturally when no attention is paid to them", denying conscious control of AMCC.

Ort29_09
The excerpt incorrectly claims that AMCC will definitely occur "if movement at a more distal joint be desired, or some other powerful resistance is to be overcome", understating how AMCC is trainable (and detrainable).

Sch36_05
Schultz's incorrect description of reciprocal inhibition also wrongly implies that AMCC cannot be trained, because reciprocal inhibition would necessarily take precedence.

Sch36_40

Schultz incorrectly claims that the (moreover undesirable) absence of AMCC during slow arm-lifting is automatic, requiring “no particular discussion” - wrongly implying that this absence of AMCC cannot be affected by training or learning.

AMCC is variable

Individual variability
N/A

Gender variability
N/A

Psychosocial variability
Justified agreement
Ort29_12
The excerpt identifies “tenseness of the muscles as a result of emotional excitement”, which agrees with the model’s finding of psychosocial variability in AMCC and moreover seems to relate to maladaptive, excessive AMCC as a symptom of music performance anxiety.

Chi46_103
The excerpt connects AMCC with fear, using the example of the “dentist’s chair”. This seems to relate to the type of maladaptive, excessive AMCC experienced as a symptom of music performance anxiety.

Bac63_06
Bacon identifies that “stiffness accompanies anxiety”, connecting AMCC with an emotional state.

Mark04_01
Mark observes that “excessive muscular work” (which by definition includes excessive AMCC) can “come from social or cultural attitudes”.

Age-related variability
N/A

Within-task dynamic variability
Justified agreement
Sch36_18
Muscular vibrato, here described by Schultz, constitutes one form of dynamic AMCC.

Sch36_32
The excerpt describes dynamically varied AMCC through different uses of AMCC (here “fixation”) for “smaller” and “larger intensities”.

Chi46_17
The excerpt reflects dynamic AMCC (here “tension”) by pondering “the timing of the tension…at what point in the time in relation to the moment of tone production…and at what point should it be relaxed?”.

Chi46_28

The excerpt implies dynamically varied AMCC by differentiating the “particular amount of” AMCC (here “tension”) for ‘any particular tone”.

Chi46_48
Ching describes dynamic AMCC as “the vital importance of bringing into operation exactly the right degree of tension…for any particular speed we happen to require”.

Ger07_50
Gerig asserts that the “timing and intensity” of AMCC are both important and should be “harmonious”.

Between-tasks variability
Justified agreement
Chi46_26
Ching contrasts between the “coarser” tasks of “everyday life”, in which satisfactory performance does not require highly refined AMCC, and piano playing, which requires more “difficult” AMCC.

Variability over time
Justified agreement
Stein05_10
The excerpt implies the trainability of AMCC and by extension its variability over time (see Stein05_10).

Field34_38
Fielden notes that intense AMCC (here “all-inclusive muscular…impulse”) can be reduced over time, “becom[ing] less strained…as practice goes on”.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
N/A

Varying origins of AMCC
Justified agreement
Sch36_42
Schultz correctly identifies forms of unavoidable AMCC due to some tendons passing multiple joints - in this case, the “extensors and long flexors of the fingers”, both of which pass the wrist, causing hand AMCC “even if the hand muscles proper are relaxed”, which Schultz identifies as “a fact of great importance”.

Sch36_44, Sch36_45
Schultz correctly identifies forms of unavoidable AMCC due to mechanical coupling between fingers - such that, e.g., if the “second finger is in the act of playing…while the third is lifted”, both must be in a state of AMCC (Schultz only claims unavoidable AMCC of the second finger, but both will experience AMCC due to the mechanical coupling of finger flexors as well as extensors). Schultz observes that this unavoidable AMCC “cannot be avoided in the great bulk of piano-playing”.

Chi46_35, Chi46_82
Ching correctly identifies a form of unavoidable AMCC occurring when “a particular speed of repetition” is desired - this is not explained here, but the reason is easy to surmise: muscular vibrato. Similarly, Ching observes that “rapid starting and stopping” of lateral shoulder movements causes unavoidable shoulder AMCC.

Gat65_22
Gat observes a form of unavoidable AMCC that occurs because “if fingers 2, 3 and 4 are held in a relaxed state, fingers 1 and 5 cannot be firmly fixed enough” in some cases - requiring “simultaneous contraction” in 2, 3, and 4 to support the rigidity of 1 and 5. This occurs partly due to mechanical coupling and tendinous overlaps between fingers.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Koch67_07
Kochevitsky incorrectly claims that “finger independence is achieved with the ability to press a key…without…muscle tension of nonparticipating fingers”. Due to mechanical coupling between fingers, the “nonparticipating fingers” will only behave independently if they are controlled via muscle tension.

Limitations of AMCC

Justified agreement
Ort29_44
Ortmann identifies that a “partially relaxed…arm” can allow greater control of “weight-release” from the finger-tip, because it causes a slower gradation of release compared to a “rigid arm…requir[ing] but a very minute motion at the shoulder to lift the finger-tip entirely from the key”. This agrees with the model’s finding that AMCC has limitations - notably here, it is minimal AMCC that appears superior to the alternatives, given that this minimal AMCC should also preserve enhanced proprioception.

Sch36_06
Schultz observes that AMCC (here “even the most powerful fixation”) will “give way before maximal contractions” across adjacent joints, such that “the hand or finger must remain below a certain maximum of speed” in order to “avoid displacing the larger arm-units”. This illustrates a limitation of AMCC in that it is unable to fully dampen all potential perturbations and reactions.

Sch36_20
Schultz notes correctly that near-maximal AMCC prohibits certain movement and activation patterns (e.g. muscular vibrato) because near-maximal contractions leave insufficient room for further contraction before reaching the muscle’s limit, making “contraction…for the purpose of producing movement…an impossibility”. This implies that muscular vibrato may at most “be moderate in intensity”.

Sch36_36

Schultz correctly observes that AMCC alone is insufficient to cause “skilful, well co-ordinated…movements”.

Ger07_44
Gerig identifies that AMCC can be insufficient to completely dampen perturbational reactive forces when “considerable amounts of velocity and dynamic intensity are needed and particularly when a staccato touch is desired”. This limitation relates to Sch36_06 and Sch36_20.

Dea17_13
The authors observe that AMCC is decreasingly possible as limb segments approach the limits of their ranges of motion: for example, “when fingers are at full extension, it is impossible to properly stabilize the joints”.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
N/A

Assessment of model findings: Positive effects of AMCC

Sensorimotor effects

General

Justified agreement
Field34_26
Fielden equates optimal AMCC (here “resilience”) with “good tone and…right physical technical conditions”, implying AMCC’s general sensorimotor performance benefits.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Matt11_02, Matt14_01, Matt14_04, Matt14_08, Matt14_11, Matt14_15, Matt14_21, Matt14_22, Matt32_11, Matt32_12
Matthay’s claim that “all good technique…depends on” three forms of relaxation (relaxation of antagonistic muscles, relaxation of arm muscles, and immediate relaxation of tone-producing muscles) does not account for the significant positive sensorimotor effects of AMCC. The same applies to his claim that “Ease in Technique and Expression hence demands…completely…[to] relax all muscles opposite to the ones required to do the work of tone-production”, that “perfect freedom” requires “elimination of the opposite muscular-activities”, that the “Relaxation of all un-needed muscles” permits “playing with the ease and freedom that might be possible”, that avoidance of AMCC allows “absolute freedom from all restraint…at the Pianoforte”, that AMCC prohibits playing “with ease, or in

response to our wish[es]", that AMCC "shall certainly spoil all our playing", preventing "[p]erfect freedom", and that AMCC will "necessarily" cause "disabling effects" and "spoil your playing".

Ort29_10, Ort29_26, Ort29_30
The excerpts ignore AMCC's broad sensorimotor benefits, suggesting that any AMCC that "exceeds the amount of resistance which the movement is to overcome…is wasted effort and serves no physiological purpose". Similarly, "more rigidity or less than necessary [required to transmit the desired force to the desired point in the proper time] will produce an incoördinated movement" oversimplifies neuromuscular control and AMCC's effects on it. Or similarly again, "there must be corresponding relaxation in the antagonistic muscles in any coördinated movement"; given this, the looseness of the finger tendon in Ort29_30's example is reliant on the assumption that antagonist relaxation is indeed occurring.

Mark04_32, Mark04_38
Mark incorrectly claims that "co-contraction makes movement more difficult and "inhibits movement"", implying that AMCC necessarily impedes ease of movement (when it can also aid ease of movement).

Accuracy and precision

Justified agreement
Cal03_13
The excerpt connects "absolute and unfaltering control" with AMCC via its requirement of an elasticity implied to involve AMCC.

Stein05_02
The excerpt connects AMCC with precise, graded movement.

Ort29_22
The excerpt relates "very fine degrees of coördinated movement" with "activity in the antagonists." Still, inertia might be an exception to the claimed requirement of "external resistance" to cause contraction (and moreover perhaps the notion of a wilful contraction still being possible despite a lack of resistance).

Schm35_09
The excerpt suggests that "slow and controlled motions" generally involve AMCC ("simultaneous, though uneven, contraction of the complementaries"), supporting AMCC's use for accurate, controlled movement.

Sch36_05, Sch36_12
Schultz observes that "a movement is made more delicately and smoothly because of contrary tension", connecting AMCC directly with accurate, precise movement. Similarly, he sees AMCC as "absolutely necessary to precision in piano technique", allowing "the subtlest control of intensity".

Chi46_42
Ching correctly identifies the use of multijoint AMCC (here "tension") to aid in "produc[ing] a sound of the right tonal value".

Chi46_89

Ching recommends to “take the greatest possible care” to use AMCC (here “tension”) to prohibit rotary perturbations of the forearm, as otherwise “you will never be able to obtain as much control of tone as you would be able otherwise”.

Gat65_04
Gat observes that for “controlled movements”, AMCC occurs above the level of “natural muscle tonus”. It is not necessary to nitpick over whether this AMCC will or merely should occur because “controlled” itself is loosely defined such that it could conceivably support either interpretation.

Gat65_25
Gat advises that AMCC (here “firmness”, which he equates to AMCC in Gat65_22) is a “prerequisite” for “dynamic shaping of…chords”, allowing the pianist to “reproduce even the most delicate dynamic nuances”; the absence of this AMCC will instead “lead to jerky and clumsy playing”.

Tub00_05
The authors observe that AMCC is “crucial for the elegance of movement and is the main component of the control of velocity of the body segment”.

Ger07_49
Gerig notes the function of AMCC to control the “right degree of speed and force” when depressing a piano key.

Fras11_23
Fraser observes that AMCC can provide “precise control” of note duration.

Justified disagreement
N/A

Unjustified agreement
Chi46_06
Ching rightly observes that eschewing AMCC “would certainly prevent us from controlling tone as well as we might otherwise do”, but this lacks explanation.

Unjustified disagreement
Stein05_47
Rupert appears incorrect in attributing to Steinhausen the position that “control” occurs as a result of “relaxation of all non-participating muscles”; see Stein05_02.

Matt14_05, Matt14_06, Matt14_12, Matt14_14
“Eliminating all contrary exertions…renders possible the acquisition of accuracy” is incorrect given AMCC’s role in movement accuracy. Similarly, AMCC is not necessarily a “fatal obstacle against the attainment of…Agility”, nor will AMCC necessarily “destroy all accuracy and subtlety in Expression”, nor will it “preven[t] the attainment of all certainty and subtlety of technique of every kind”, nor make it “quite impossible to direct the required exertions with that complete nicety and mastery that is imperative for artistic playing”.

Ort29_11
Ortmann incorrectly claims that rigidity present at a joint where movement occurs “seriously interferes with…accuracy…of the movement”, wrongly implying that AMCC necessarily impedes accuracy when in fact it can also aid accuracy.

Matt32_01, Matt32_13
Matthay incorrectly claims that AMCC (“antagonistic exertions”, “stiffness,” and “rigidity”) precludes “accuracy in tone”, “ease in performance”, and “control of tone”.

D’Ab64_04
D’Abreu falsely claims that “there is common agreement as to the role relaxation plays in effective control”.

Fras11_54
Fraser incorrectly asserts that AMCC must cause “inaccuracy” and should be “eliminat[ed]” in order to control a “wild, almost violent movement”.

Efficiency

Justified agreement
Sch36_14
Given the context (that Schultz is criticising relaxationist pedagogy), Schultz implies AMCC’s positive effects on movement efficiency.

Chi46_80
Ching identifies insufficient AMCC as usually causing “the failure to begin…efficiently”, for reasons he expounds thoroughly in adjacent passages (e.g., stability and force-transfer).

Ger07_49
Gerig observes that AMCC helps movement occur with “maximum efficiency” via base stability.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Matt08_10
Matthay is incorrect in claiming that AMCC would “unfailingly prevent…technical efficiency”, given AMCC’s beneficial effects on motor efficiency.

Ort29_49
Ortmann is incorrect in claiming that “hyper-tension” (equivalent to AMCC; see Ort29_48) is biologically wasteful. Given AMCC’s beneficial effects on movement efficiency (among its other effects), it is inappropriate to describe AMCC as necessarily wasteful.

Inter- and multi-joint coordination and transference

Justified agreement
Stein05_03
Steinhausen suggests that forces generated by the hand muscles “would not succeed in reaching the fingers themselves” via AMCC.

Stein05_32

Steinhausen observes that joint stiffness via AMCC is “necessary for transmitting the vital energy to the finger tips”, correctly identifying AMCC’s function for multi-joint force transfer.

Ort29_09
The excerpt identifies that AMCC (“flexors and extensors…simultaneously contracted” enables multi-joint dynamics, such as “movement at a more distal joint”.

Ort29_20
The excerpt confirms that AMCC is important for multi-joint force transfer; in this case, by transferring arm and/or hand forces through the finger and into the key, to produce a tone of “even moderate loudness”. It seems that the only way to disprove the rule stated in the excerpt would be to play the piano standing up, or to add artificial joint stability (e.g., via an elbow brace); neither approach would be practical for playing the piano in general, and both would carry far greater disadvantages.

Ort29_27
The excerpt advises that “sufficien[t] rigid[ity]” is required to “transmi[t]” the “weight of the arm…through…to the keyboard”, supporting AMCC’s function for multi-joint force transfer.

Field34_14
The excerpt correctly identifies that AMCC must occur in order to allow the “hand” and “forearm” to be used together ‘“of a piece’”, rather than independently and non-coordinately.

Field34_15
The excerpt correctly advises that AMCC must occur as a “double anchorage” across joints, e.g. allowing the “wrist…to become one with and assist the forearm”, or the forearm with the upper arm.

Sch36_21
Schultz’s example exercise to demonstrate “muscular vibrato” involves multijoint coordination via AMCC: “the elbow and shoulder must grow tighter” via AMCC (“stiffening”).

Sch36_24
Schultz correctly denotes supporting contractions ’function in transferring forces across multijoint systems; while this may technically be possible with one-sided contractions in some cases, this is prohibitively challenging and therefore AMCC is the typical source of this support.

Chi46_16, Chi46_17
By pondering the “amount of tension necessary at the joints of transmission” for purposes of “learn[ing] control of even the most simple act of piano playing”, Ching implies the desirability thereof - which amounts to an agreement with its importance for multijoint coordination.

Chi46_34, Chi46_35, Chi46_36, Chi46_55, Chi46_71, Chi46_76, Chi46_96, Chi46_98, Chi56_03
Ching refers to complex states of AMCC (here “tension”) across multiple joints simultaneously.

Chi46_72, Chi46_79, Chi46_86, Chi46_88, Chi46_92, Chi56_04

Ching correctly observes the role of AMCC in transferring force efficiently across multiple joints.

Bow61_04
Bowen discusses multijoint transference and coupling via “lock[ing]” joints into a “firm state” with AMCC, contradicting his earlier advice (e.g., Bow61_03: “Do not allow any tug-of-wars”).

Bow61_06
Bowen advises the use of AMCC to allow the wrist to “act as a bridge”, transferring force across a multijoint kinetic chain.

Ger07_33
Gerig observes that AMCC can transfer the “weight of the arm” into the keys through the “finger and hand”.

Ger07_45
Gerig denotes the necessity of AMCC “in order to keep the non-playing fingers from moving”, as described in Sch36_44 and Sch36_45.

Ger07_47
Gerig observes that AMCC occurs simultaneously as “the finger moves independently” and “the base itself…engag[es] in long-line horizontal and even vertical movement”, achieving a “sense of full and appropriate cooperation among all of the members” - representing a multijoint coordination occurring with the presence of AMCC.

Dea17_03, Dea17_12
The authors discuss AMCC’s role in force transfer: e.g., “muscles on both sides of the knuckles and finger joints isometrically contract to stabilize these joints so that force can be efficiently transmitted to the key”, and “the forces generated by the arm [may] be transmitted more directly”. In contrast, “when playing with looser joints, some of the energy of the keystroke is dissipated before it is imparted to the key” - “dissipated” here meaning converted to undesired forces that are unproductive for control of key depression.

Justified disagreement
N/A

Unjustified agreement
Ort29_07
The excerpt’s central claim that “sufficient rigidity must be present” is untrue, as movements can still occur without “fixed fulcra” - and moreover, fulcra can behave as “fixed” without rigidity, due to inertia. For example, sitting in a neutral position, flexing the forearm towards the body (in the elbow joint), then forcefully ‘throwing ’the wrist and extending the forearm, without a rigid, fixed elbow (which is a fulcrum here), still allows the forearm to forcefully extend - but has the added result of the upper arm being pulled away from the body, if the movement is forceful enough to overcome the upper arm’s inertial tendency. In this case, the forceful movement being considered (that of the forearm extending outwards as if ‘throwing ’the wrist) still occurs; the entire lever has however moved position due to the lack of fixation of the elbow (and of the shoulder). If the excerpt instead suggested that sufficient rigidity must be present if fixed fulcra are desired and anchoring via inertia is insufficient, it would probably be more correct. Additionally, “forceful movement” seems vague, as all movements require some force; this is not especially

pedantic given the context of the excerpt, as Ortmann is discussing physiological and biomechanical minutiae at great length.

Ort29_19
The excerpt claims that the thumb “must be fixed to act as a fulcrum” when “it is desired to abduct the second finger toward the thumb”, but this seems false. For example, the thumb could instead simultaneously adduct towards the index finger at the same time; alternatively, the thumb could abduct away from the index finger.

Ort29_28
The excerpt claims that “relative fixation [here AMCC] of all joints over which [a tendon] passes is necessary to permit the force to act at the desired point”, but this is somewhat incorrect; a portion of the force may still reach the desired endpoint (though inefficiently) without this AMCC.

Sch36_33
Schultz correctly observes that AMCC can make multi-joint transference of forces “more smoothly and efficiently” than without AMCC - but does not provide justification.

Unjustified disagreement
Field34_07
Fielden incorrectly claims that AMCC (here “stiffness”) detracts from “independence of fingers”, when AMCC can aid multi-joint dynamics including finger independence.

Whi61_01
Whiteside wrongly implies that AMCC for force transfer is unnecessary by claiming that the “bony structure” of the hand is sufficient to “easily transmit the power of the large muscles for tone production”. The finger bones themselves, lacking inter-joint stability via AMCC, cannot efficiently transmit this power into the piano key without collapsing. Even stacked in a vertical position, the transfer of forces is precarious - and this perpendicular-finger coordination has only rare value regardless.

Last80_05
Last wrongly suggests that the arm “gently relaxes” in order to allow its “weight to be transferred to the sound spot by a firm finger”; this is not only incorrect (most of the arm weight would remain supported in the glenohumeral joint, not transferred to the key) but also overlooks the function of AMCC for transfer of forces across joints.

Fras11_77
Fraser incorrectly asserts that AMCC (here “static muscular contractions…at the joint”) will “block” forces so that they “simply can’t get through”.

Dea17_06
The authors suggest that upper arm AMCC would “work against a pianist’s ability to play…fast scalar passages”, contradicting their earlier observation that AMCC is important for multijoint force transfer (which is certainly relevant to fast scalar passages).

Internal model generation
N/A

Proprioception

Justified agreement
N/A
Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Matt14_19
Here Matthay incorrectly claims that one must “eliminate…contrary exertion” (AMCC) in order to “estimate the weight of an article” in hand, contradicting research that supports AMCC’s function as a proprioceptive aid.

Sch36_43
Schultz makes a similarly false claim as Matthay in Matt14_19.

Range of motion and individuation

Justified agreement
Ort29_29, Ger07_35, Dea17_03
Ortmann, Gerig, Deahl, and Wristen all identify common movements that can only occur via AMCC: “the biceps…flexes the elbow and supinates the fore-arm…when only one of these motions is made the other is not simply eliminated, but is prevented by appropriate contraction of the antagonistic muscles”.

Knud07_01
Knudson observes that AMCC overrides reciprocal inhibition when it is required “to push or move in a specific direction”.

Justified disagreement
N/A

Unjustified agreement
Ort29_35
This excerpt is particularly puzzling and easily disproven. Self-experimentation quickly demonstrates that the forearm can assume a variety of positions (indeed comparatively even more positions) without “fixation of the humerus” (here fixation is used scientifically, to mean “held in position”). Ortmann also invites confusion by using “fixation” to refer to a bone (the humerus, which implies AMCC at the glenohumeral joint), then on the very same page using “fixation” in reference to a joint being made rigid by AMCC, not clarifying between these two usages.

Unjustified disagreement
Matt08_07
Matthay is incorrect in claiming that any AMCC will render “all action and movement extremely stiff and restrained”; AMCC can decrease movement restraints in many contexts.

Schm35_06
Schmitz claims that “relaxation and depression of the shoulder-girdle allow an easy maintenance of the desired depth at elbow”, discounting AMCC (which prohibits relaxation) and its beneficial effects on range of motion (including at the elbow).

Signal-to-noise ratio (SNR)
N/A

Speed and power output

Justified agreement
Ort29_41
The excerpt observes that AMCC (here “rigidity”) was required to produce a “true fortissimo”, supporting AMCC’s role in power output. However, the excerpt contradicts several earlier statements: playing “quite loud” with a “relaxed wrist and arm” is impossible according to Ort29_38, while making a descending arm-movement “with rigidity” rather than “partial relaxation” is impossible according to Ort29_40.

Ort29_47
The excerpt agrees with the model that intense AMCC (“utmost rigidity”) is important for fast movement (here, a “fast succession of staccato movements” constituting “vibrato touch”); what is odd is that Ortmann has already spent significant amounts of time defending the opposite position from varying angles - that is, suggesting that AMCC is detrimental (or impermissible, incoördinated, etc.), in categories of movement that would include fast successions of staccato notes.

Ort29_48
Here Ortmann observes further value of AMCC for “instantaneous transfer of force”, “speed of movement”, and “rapid…movement” - still contradictory with earlier, opposite claims (e.g., Ort29_11).

Field34_14
The excerpt correctly identifies that AMCC can “hel[p]…speed of attack”.

Field34_31
Fielden observes that in “swift” playing and “where the highest effort is called for”, AMCC (here “tension”) must be present.

Sch36_05
Schultz correctly identifies that “movement itself takes place more promptly if a state of tension exists between muscle and bone” via AMCC, acknowledging one of AMCC’s benefits for movement speed.

Sch36_10
Schultz claims that it is “impossible” to execute rapid scales or octaves without AMCC, implying AMCC’s benefits for movement speed.

Sch36_19
Schultz identifies one use of AMCC to increase movement speed: because some muscles may relax more quickly than their antagonists can contract, the movement occurs faster: “at a rate which conforms to [the agonist]’s period of relaxation, not to [the antagonist]’s period of contraction”.

Chi46_46, Chi46_47
Ching associates the “highest speeds of repetition” with “the maximum” AMCC (here “tension”).

Chi46_48, Chi46_51, Chi46_52, Chi46_76, Chi46_77, Chi46_78, Chi46_87, Chi46_88, Chi46_90, Chi46_98, Chi46_102, Chi56_04
Ching positively associates playing at “high speeds” with AMCC (here “tension”), formulating that AMCC at the “joint of movement is dependent on the speed of sequence of the movements”.

Chi46_58, Chi46_59, Chi46_71, Chi46_87, Chi46_88, Chi46_91, Chi46_98, Chi56_04
Ching associates playing “louder” with more AMCC (here “tension”), formulating this into a “law of technique”.

Chi46_74
Ching identifies the speed benefits of taking up “slack” in muscles and tendons via AMCC.

Gat65_25
Gat observes the function of AMCC (here “firmness”, which he equates to AMCC in Gat65_22) for “transmitt[ing]…force” to the keys. Without this AMCC, “gaps caused by waste of force at the fingers have to be filled up”.

Ger07_30
Gerig observes that lack of AMCC for stability will “seriously hampe[r] velocity” due to displacement of the base.

Justified disagreement
N/A

Unjustified agreement
Ort29_52, Ort29_53, Ort29_55
Ortmann incorrectly claims that “we simply cannot play loudly and be relaxed to any extent. The mature artist still needs rigidity sufficient to balance the force necessary for production of the desired tone”. In fact, it is possible to play loudly with an “extent” of relaxation - just not total relaxation. Similarly, it is incorrect that “for all finger-strokes beyond the soft degrees, some muscular fixation [here fixation is implied to mean AMCC] of the wrist is necessary…The finger…can transmit force through its tip only to the extent that each of its joints is fixed”, and also an overstatement to claim that “all fast, very loud passages with change of direction can be played only with excess rigidity”.

Ger07_34
Gerig notes that AMCC is needed to achieve “maximum contraction” - presumably by stabilizing the base of the contraction. However, this is not strictly true; firstly, it would be more accurate to state that AMCC is needed to achieve maximum force output - as any contraction tends to be inefficient in its output of a desired force if its base is not stable, as more of the total force generated will be converted to undesired motion at the base. Secondly, maximum contraction without a stable base may be achieved against an external resistance (e.g., by pressing against a wall).

Unjustified disagreement
Matt14_03, Matt14_05, Matt14_06, Matt14_12
Matthay’s claim that “complete possible Relaxation of all muscles that should be passive” (which in Matthay’s writing clearly implies the absence of AMCC; see e.g. Matt14_01) forms the “real ‘secret ’of all good tone-production (including Agility) at the Pianoforte” contradicts research confirming AMCC’s beneficial effects on movement speed. Similarly,

AMCC is not “a fatal obstacle against the attainment of…Agility”, nor will it necessarily “prevent our attaining any true Agility”, nor “preven[t]…facility in Agility”.

Ort29_11
Ortmann incorrectly claims that rigidity at a joint where movement occurs “seriously interferes with…[the] speed of the movement”, wrongly implying that AMCC necessarily hampers movement speed, when in truth it can also aid movement speed.

Bru97_12
Bruser incorrectly claims that “co-contraction…limits speed”.

Taub05_01, Taub05_06
The excerpts wrongly claims that “there is no way you are going to be able to go fast, when you have” AMCC (here “antagonistic pulls”).

Stability (General)
Justified agreement
Ort29_06: Ortmann observes that AMCC (“simultaneous pull on both sides of the joint” is used for “stabiliz[ing]” and “making possible an immediate response to a nerve stimulus”.

Sch36_05
Schultz correctly observes that “a movement is made more…smoothly because of contrary tension”, linking AMCC to improved stability.

Sch36_24, Sch36_25, Sch36_26, Sch36_27, Sch36_37
Schultz correctly identifies supporting contractions ’role in preventing joints from collapsing. These supporting contractions occur via AMCC (here “fixation of the base”), as one-sided supporting contractions are prohibitively difficult due to exact timing and magnitude demands. This AMCC is the principal means of simplifying the necessary “force-adjustments for separate tones”. In other words, to use the example of the hand, AMCC of wrist flexors and extensors relieves the prohibitive complexity of needing individualized extensor contractions to stabilize the wrist against the reactions of finger flexion. These individual extensor contractions would need to precisely counteract the forces applied at the wrist due to finger flexion, both in terms of timing and magnitude, as otherwise they would result in undesired wrist extension; this level of precision is prohibitive. In contrast, AMCC of wrist flexors and extensors relieves the required precision of timing and magnitude for each instance of finger flexion, instead allowing a simpler overall stabilization that “is capable of withstanding various degrees of reaction” while “need[ing to] show no change in condition”. However, Schultz is incorrect in claiming that the absence of a stable base via AMCC would cause the accompanying movement’s speed to be “directly determined by the…force-adjustment of the base”; this force adjustment (equivalent to the wrist extensor contraction in the example immediately prior), though it does have some effect on the movement speed of the “playing-unit”, would never “directly determin[e]” said speed.

Chi46_21, Chi46_53, Chi46_55, Chi46_59, Chi56_04
Ching correctly observes AMCC’s function for joint “stabilisation”, including “the amount of resistance to reactionary movement”, which is “complicated by” factors such as “inertia”, perhaps hyperbolically lionizing it as “so vitally important in all advanced technique”.

Chi46_68

Ching rightly identifies the challenges of joint stability without AMCC and suggests AMCC instead - recalling Sch36_25, etc. (see above).

Ger07_30
Gerig identifies that AMCC can provide much-needed joint stability against displacement. However, his other method of achieving stability, by “weight resting upon the playing lever by downward muscular exertion”, is partly flawed. Firstly, if “downward muscular exertion” is applied, force and not weight will result. Secondly, downward force upon the playing lever couples with the action of depressing a piano key; this force will not stabilize but amplify the reactive force from the impact of the finger on the key, unless the force is timed after key depression - a nuance that Gerig fails to mention. In fact, Gerig does not mention this reactive force from the key whatsoever here; he is focused instead on the “moving lever…react[ing] against the base to which it is attached” - which is best described not as a reaction but as part of the primary action of the moving lever itself, which exerts an equal and opposite force on its base due to Newton’s Third law. Still, Gerig’s “downward muscular exertion” can counteract this opposite force of the moving lever on the base - although AMCC (itself implying downward muscular exertion) is typically a preferable solution due to its relevant advantages here - including greater speed and superior error compensation.

Ger07_42
Gerig observes one benefit of AMCC-derived stability - that the AMCC may be “maintained at a single level-strong enough to counter the reactions of the many minute force variations present”. In contrast, one-sided contractions for effective stability would have to respond precisely in timing and magnitude to all variations in destabilizing forces - an impossible task given the nonzero travel times of neuromuscular signals, and one that would be prohibitively difficult even if possible.

Ger07_49
Gerig notes that AMCC’s contribution to joint stability is an element of “expert functioning” and helps to achieve “maximum efficiency” of movement.

Dea17_03
The authors observe AMCC’s function for “stability”: e.g., “muscles on both sides of the knuckles and finger joints isometrically contract to stabilize these joints”.

Justified disagreement
N/A

Unjustified agreement
Ort29_36, Ort29_37
It appears self-apparent that one can maintain a joint at “a given position in space” without “all other joints” engaging in “fix[ation]” (here implying AMCC, rather than immobility). Instead of fixation, the muscles controlling joints simply can contract against gravity. Even if the standard definition of “fix” had been adopted, the claim is still false; for example, the wrist can be held at a “given position in space” via compound movements of the forearm and upper arm that cancel out, resulting in a static wrist position. To adopt Ortmann’s mechanical arm as an analogy, the joints could be hanging from strings suspended from the ceiling, rather than fixed using “set screws” to approximate AMCC. It is also easily disproven, in similar fashion, that “all other joints must be fixed” in order to “merely maintain the finger-tip in a fixed position upon a key”.

Ort29_38
Ortmann incorrectly claims that increasing “contraction” to increase force “exerted upon the finger-tip” also necessitates “greater fixation in all joints acting as fulcra” (fixation here meaning AMCC). While such fixation should be desirable for stability, it is by no means mandatory.

Matt32_03, Matt32_04
Matthay mistakenly suggests that joint fixation (here immobility) necessarily causes stiffness (here AMCC); in fact, it is possible to fixate joints without the presence of AMCC (e.g., via external resistance, such as pressing one’s palm against a wall to fixate the wrist).

Fras11_31
Fraser identifies that if AMCC is absent at a joint, the joint “collapses” - but this collapse would only occur if sufficient forces were applied such that the joint’s passive resistances were overcome.

Unjustified disagreement
Matt32_02
By correctly observing that AMCC (here “stiffening”) must occur if a joint is fixed (here “made stable and immobile”) while movement occurs at the same joint, and labelling this stiffness as “a terrible mistake, leading to a paralysing stiffening”, Matthay denies the value of AMCC for joint stability - yet then contradicts himself by proposing a solution that in fact also demands AMCC: “this stable condition can only be achieved by supplying an invisible stress from the next-door portion of the limb behind the joint”.

Matt32_09
Here Matthay incorrectly claims that “steadying of the joints” must be achieved by “a countering action from the next adjacent part of that limb”, and “never” by AMCC (“simultaneous exertion of antagonistic or ‘contrary ’muscles”); while unipolar contraction is indeed one method of achieving a stable (steady) joint in some situations, it is not the only one - and AMCC is a more robust and common strategy for joint stability.

Matt32_16
Matthay incorrectly claims that “immobile, stable, or resisting” joints should never be achieved by “fixation” (here equivalent to “stiffness”, meaning AMCC). This ignores the value of AMCC for joint stability.

Chi46_85
Ching contradicts his acknowledgment of the challenges of one-sided contractions for stability (see Chi46_68) by wrongly suggesting “pressure transference” as a feasible means of joint stability.

Stability (Upper limb)

Justified agreement
Stein05_10
The excerpt observes the use of AMCC for stability - for example, “the shorter hand muscles surrounding the wrist…lend[ing] this joint the necessary stability of resistance”, in accordance with the model’s finding of AMCC being supportive of upper limb stability.

Ort29_18

The excerpt advises the use of “rigid” joints to counteract the “upward jerk” resulting from “impact…upon the key”, according with the model’s finding of AMCC for upper limb stability.

Sch36_21
Schultz’s demonstration of muscular vibrato involves AMCC for stability: “the elbow and shoulder must grow tighter”, so that the “reactionary movement of the arm [will] become less extensive”.

Chi46_14, Chi46_70, Chi46_84
Ching recognises the “reactions of piano technique” and the danger they pose to “perfectly controlled” playing, correctly identifying AMCC as the principal solution to these reactions. He properly considers this AMCC-based stability alongside the inertia of varying limb segments. One example of this is “rotary stabilisation” of the forearm to address reactions from “finger touch”.

Gat65_21
Gat identifies AMCC as the primary solution for hand stability, by using the “deep finger flexor…simultaneously…[with] the extensors”, to “prevent…the hand from shifting” due to the same flexor contractions.

Tub00_03
The authors identify that dynamic AMCC provides “shoulder stability” and “dynamic stabilization”.

Ger07_32
Gerig rightly observes that AMCC can prevent perturbation from the reactive force arising from the finger impacting the key.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Ort29_10: Ortmann notes that hand rigidity via AMCC in the wrist prevents a reactive movement of the “hand-knuckle” when “the finger-tip strikes the piano-key”, observing the function of AMCC in achieving joint stability.

Stability (Lower limb)
N/A

Stability (Trunk)
Justified agreement
Sch36_30
Schultz identifies the necessity of trunk AMCC (“the body itself must be fixed at the hips”) in order to resist certain “powerful movements of the arm”, for example during “a rapid succession of fortissimo chords”.

Chi46_75, Chi46_76

Ching correctly observes the use of trunk AMCC (here “tension at the waist”) to “obtain really loud tone”. More precisely, the loud tone can be obtained without this AMCC, but the AMCC provides much-needed stability that improves the efficiency of the playing and absorbs and dampens reactive forces that would otherwise displace the body.

Chi46_100, Chi46_101
Ching notes the importance of “bodily stability”, requiring “voluntary tension at the waist”, for “note accuracy in skips”.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
N/A

Positive health effects

Justified agreement
Chi46_83
Ching makes an attractive and apt metaphor by comparing pharmacology, which uses “the most deadly poisons, in the correct doses”, to the positive and negative health potentials of AMCC, which themselves are partly dose-dependent.
Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Matt14_09
The excerpt makes the exaggerated, unsubstantiated claim that “stiffening” (and therefore AMCC, in Matthay’s terms) causes “terribly severe…shocks” and “maltreatment” that the “[t]endons could not withstand…for any length of time, were they even of steel”. This contradicts AMCC’s potential for positive health effects.

Assessment of model findings: Negative effects of AMCC

Excessive AMCC
Justified agreement
Matt14_18
Given that Matthay has previously adopted accurate, scientific usage of “rigid”, here he appears to correctly (though hyperbolically) caution against excessive and static AMCC by critiquing the “rigid wrist” as a sign of “ignoran[ce] of the very first physical principles of all Technique”

Ort29_56
Ortmann’s warning against “maximum rigidity” (here meaning maximum AMCC) accords with the model, which found that maximum AMCC is rarely if ever valuable.

Chi46_33, Chi46_36
Ching rightfully notes that excess AMCC can “affect[t] tone control adversely in an indirect way”, and cause fatigue.

Chi46_44, Chi46_48
Ching correctly observes that excessive AMCC (here “tension”) can result in “what we commonly call ‘stiff playing’”; ‘stiff ’here meaning excessively co-contracted.

Bow61_06
Bowen suggests that excessive AMCC, to the point of a joint being “rigid and unyielding”, will “impede production of beautiful tone”.

Gat65_23
Gat rightly cautions that “excessive” AMCC “may result in cramping”.

Koch67_08
Kochevitsky warns that AMCC, “if prolonged, would result in a cramp” - apparently reflecting the contrasting health effects of dynamic and static AMCC.

Mark04_31
Mark cautions that “excessive co-contraction makes movement more difficult”.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Cal03_11
The “highest possible state” of tension during performance of a Chopin Prelude implies excessive AMCC, as the model found that maximal AMCC is not indicated as beneficial in piano performance, except perhaps in rare, extreme cases.

Ort29_55
By claiming that fast and loud passages can only be played with “excess rigidity” (meaning excess AMCC), Ortmann indirectly denies the possibility of truly excessive AMCC. In other words, falsely equating “excess” and “necessary” AMCC, by claiming that the former is required for fast and loud playing, prohibits the proper meaning of “excess” by implication.

Sensorimotor effects

General
Justified agreement
N/A

Justified disagreement
N/A

Unjustified agreement
Chi46_27
Ching rightfully observes that AMCC (here “tension”) “in the wrong joint can be…disastrous” - but this lacks justification.

Unjustified disagreement
N/A

Efficiency
Justified agreement
Sch36_22
Schultz correctly identifies that AMCC can be more fatiguing - here in the case of the “vibrato co-ordination”, because this requires AMCC and permits “no rest period whatsoever”.

Kent76_03
Kentner observes that excessive, undesired AMCC (here “stiffness”, which he defines as akin to muscle spasm) can impair efficiency.

Tub00_05
The authors note that AMCC without “good adjustment…generates fatigue…uselessly consuming too much energy”.

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
N/A

Flexibility
N/A

Inter-joint transference
N/A

Proprioception
N/A

Signal-to-noise ratio (SNR)
N/A

Speed and power output
Justified agreement
N/A

Justified disagreement
N/A

Unjustified agreement
N/A

Unjustified disagreement
Sch36_13
While Schultz’s conclusion that AMCC without partial reciprocal antagonist inhibition necessarily inhibits movement speed appears reasonable, evidence suggests the truth is more complicated, which casts doubt on Schultz’s claim that such AMCC for an “isolated act” is “at a distinct disadvantage”.

Negative health effects
Justified agreement
Chi46_83
Ching makes an attractive and broadly reasonable metaphor by comparing pharmacology, which uses “the most deadly poisons, in the correct doses”, to the dose-dependent positive and negative health potentials of AMCC.

Tub00_05
The authors observe that AMCC “without good adjustment” can cause “muscle pain”.

Mark04_02, Mark04_31, Mark04_32, Mark04_38
Mark cautions that “co-contraction” is “potentially injurious” and that “excessive co-contraction…can be a cause of injury”.

List18_01
Lister-Sink advises that “unnecessary and continuous” AMCC can lead to “fatigue, pain or injury”.

Justified disagreement
N/A

Unjustified agreement
Wins98_02, Wins98_05
The authors incorrectly imply that AMCC causes all upper limb pain: “there would be no upper limb pain if the cellist’s movements were…without tension…alternating relaxation and contraction”. Similarly, “if…no tension [is] present in the neck or back, playing the cello should cause no problems at all” incorrectly implies that all playing-related pain is caused by AMCC (here “tension”).

Mark04_01
Mark observes that “injury comes from…excessive muscular work” (which by definition includes excessive AMCC). However, this wrongly implies that all playing-related injury arises from excessive muscular work, exaggerating the real negative effects on health that can arise thusly.

Mark04_33
Mark claims that “injury is the result…[of] co-contraction”, wrongly implying that all injury arises from AMCC (and contradicting Mark04_01, where he instead blames “excessive muscular work” for injuries - unless he intends to equate AMCC and “excessive muscular work” (the latter which he already equates with “tension” at times), but this is not clear.

Taub05_06
The excerpt incorrectly asserts that AMCC necessarily causes injury: “antagonistic movements…[are] ruining our hands”.

Unjustified disagreement
Sch36_11
Schultz indirectly implies that AMCC (here “stiffened joints”) is never unhealthy, by claiming that “no authority in the field of medicine or physiology” believes that “stiffened joints represent an unhealthy use of the muscles which stiffen them”. This is incorrect, as AMCC (particularly, static and/or excessive AMCC) can be unhealthy and injurious.

Assessment of terminology, concepts, etc.

Excerpts here are discussed not in relation to agreement or disagreement with the model, but in terms of their terminological and conceptual usage.

General

Assorted excerpts - analysis of definitions, claims, assumptions
Cal03_12, Cal03_13
“[F]ingers…held ever with great firmness” might suggest an excessive, static AMCC, but Caland does not define “firmness”. Similarly, “the highest state of firm, yet elastic tension” does not clarify further given Caland’s vagueness about these terms too.

Stein05_54
It is difficult to interpret what Rupert means by “antagonistic motion”. If he means AMCC, then he has misinterpreted Steinhausen and Ortmann, who both favor AMCC in some cases, and correctly understood Matthay, who is vehemently opposed to AMCC.

Cort28_02
Cortot does not define “absolutely loose”, leaving it uncertain as to whether he means “totally relaxed” (a possible but impractical usage of the wrist to play a chord), or something else.

Cort28_04
Even benevolent interpretation cannot save this excerpt; playing these extra notes in Cortot’s extension/stretching exercises does not guarantee the relaxation of priorly stretched finger muscles.

Ort29_34
Here Ortmann discusses “immobility of joints” but it seems he instead means “relative immobility”, i.e., a pair of joints that move in parallel - not immobile, but immobile relative to one another. This relative immobility would typically require AMCC.

Ort29_45
Ortmann misuses “antagonistic” by implying that “simultaneous contraction of antagonistic [muscle] groups” can occur across distant, separate joints - for example, finger flexion (“pressure…at the finger-tip”) “in spite of” scapular elevation (“arm-lift”). This misrepresents the meaning of “antagonistic” in the context of AMCC. Even in simple directional terms, finger flexion and scapular elevation are not necessarily antagonistic (e.g., if the forearm is supinated, finger flexion and scapular elevation both move the finger upwards).

Ort29_46
Ortmann uses “negative movement” unclearly - if it means ‘movements away from the instrument’, then this contradicts the claim that “the movement is not directed toward meeting any external resistance”, because (e.g.) an arm-lift away from the instrument meets the resistance of gravity. Alternatively, if it means ‘movements aided by gravity’, this still contradicts the same claim- as (e.g.) an arm-drop onto the keyboard will still meet the inertial resistance of the keys.

Matt32_02

Matthay, apparently confused, falsely differentiates between two identical cases of joint stability achieved by AMCC: “fixation of the joints…leading to a paralysing stiffening of the whole limb” and a “stable condition…only…achieved by supplying an invisible stress from the next-door portion of the limb”.

Schm35_01
The excerpt begins the work on a questionable note: “rational” is not equivalent to ‘complete ’or ‘exhaustive’, and Schmitz implies the latter, but says the former - which does not bode well for the rationality of the work.

Schm35_11
While the excerpt is correct that the pectoralis major and latissimus dorsi are antagonists, yet work together to adduct the humerus, the two muscles can be considered to be working as synergists, or complementary agonists, in this function. Therefore, it is misleading, though technically accurate, to state that adduction will “demand the action of two muscles which are antagonists”; it is important to recall the meaning of ‘antagonist ’ muscles, as opposing in function, so that when two muscles are behaving agonistically/synergistically, they are principally considered as such. Now, if the proposed case were one in which the pectoralis major and latissimus dorsi were also functioning as antagonists simultaneously, the situation would be somewhat more complex; in this case, it would be important to first determine which function (of either the function where the muscles behave as agonists, or the function where the muscles behave as antagonists). Only then could we decide whether the muscles were primarily agonists or antagonists in this situation - but regardless, the case would be that they were simultaneously operating as both. This is simply a result of the fact that muscles can have multiple functions (and can at times operate these functions simultaneously).

Sch36_28
The excerpt appears flawed in numerous respects. First, “cause the base to move upward” is incorrect - as depending on factors such as which joints are in question, and their orientation in space (e.g., with the metacarpophalangeal joints and wrist - is the palm supinated or pronated; let alone the forearm, or the rest of the body?), the base could conceivably move in any direction. Second, Schultz seems to misunderstand how AMCC at a particular joint affects the conditions of the joint: specifically, it appears that he conceives of the forces generated by agonist and antagonist as two bipolar scalar values (e.g., at the elbow, +50 units of force from the biceps and -50 from the triceps), which would validate his claim that “otherwise the reactionary force added to the force of the lifting muscles would cause the base to move upward during key-depression”. This is all incorrect - the forces generated by agonist and antagonist are vector quantities, their combined effect being determined not only by their magnitude (e.g., 50 force units) but their directions - which exist not on a bipolar, one-dimensional axis, but in three-dimensional space. In the case of the elbow, this means that the combined effect of the forces generated by biceps and triceps co-contraction is converted to two axial pulls on the forearm that are nearly parallel in direction, and therefore the example of 50 force units from each muscle would result in (roughly; the example is simplified to emphasize the relevant points) 100 force units of pressure between the articular surfaces of the forearm and upper arm at the elbow joint. Therefore, the “reactionary force added to the force of the lifting muscles” would not “cause the base to move upward during key-depression”, unless the reactionary force (e.g., in this case, the force generated by contraction of the wrist flexors located in the forearm, which pulls equally on the hand as it does on the upper arm due to Newton's third law) exceeded 100 units. Third and finally, Schultz’s claims about the nervous system, including “reflexes”, “nerve impulses”, the “spinal cord”, and the “brain”, are almost entirely spurious. The claims

are inexcusable even for 1930s-era neuroscience, as comparatively more-accurate understanding of the nervous system had been achieved long prior (e.g., Sherrington, 1906).

Chi46_10
The excerpt seems to make the same error as Sch36_28 (above) in conceptualizing agonistic and antagonistic forces as bipolar scalar values, which undermines the metaphor of “two opposite guy ropes attached to a tent pole which, by their equal and antagonistic tension, prevent the pole from moving”. In fact, while the tensions may be roughly equal, their directions are not antagonistic - unless the ropes were perpendicular to the tip of the pole, in which case they would actually fail in immobilizing the pole. The more the directions of these two tensions are parallel (i.e., the closer the base of each guy rope is to the base of the pole), the more the pole would be immobilized - in plain disagreement with Ching’s wording. Furthermore, the example of perpendicular guy ropes (which contrast with the arrangement of tendons attached to bones, the former of which are never perpendicular to the bones themselves) illustrates further the flaw that led Schultz36_28 to imagine the base to “move upward” (in the tent pole example, equivalent to the tip of the pole swaying from its original position).

Chi46_41
The excerpt presents an interesting hypothesis for why AMCC is necessary in human (versus robotic) piano technique. However, the hypothesis does not account for certain effects of AMCC that are valuable even in non-human movement contexts; robot movement can benefit from AMCC too (see for example Büchler et al., 2023). Given its overlooking of certain effects of AMCC, the hypothesis presented in the excerpt can be safely rejected.

Chi46_95
Strangely, Ching claims it is possible to produce “considerable tension…in those antagonistic muscles which produce tension at the wrist joint”, which are somehow “limited to the muscle of the hand”, implying incorrectly that any and all extensors passing the wrist (e.g., extensor carpi radialis longus) are not part of “those antagonistic muscles”.

Bon53_08
The excerpt uses vague and unclear terminology, such as “reflex motion” and “muscular motion”. Bonpensiere frequently resorts to undefined, idiosyncratic terminology, which seem to have the effect of obscuring his real meanings (which themselves often appear unfounded or inadvisable).

Bac63_03
Bacon is incorrect in claiming that “the pianist never need use downward force to produce even the most powerful sounds…Gravity gives all the power the piano will take”. At the piano, a free-falling arm (somewhat dependent upon the pianist’s physique, and the particular instrument) will produce a sound that amounts to approximately a mezzo-forte.

Gat65_24
Gat seems to use “fixing of the hand”, of “the wrist”, and of “the fingers” interchangeably in this confusing excerpt.

Koch67_03
Kochevitsky wrongly claims that “it is not muscle, but nerve command…that is being strengthened” - a central claim of the entire work, which is repeated and expounded upon

at length, controverting earlier approaches that concluded muscle dynamics are important (and overlooked the role of the nervous system and brain). The truth appears to lie between these two extremes - which Kochevitsky begrudgingly acknowledges by agreeing that "muscular conditions…are important, but…secondary", and that "it is possible to strengthen the muscles and increase their endurance". Indeed, development of skilled sensorimotor performance does have significant longer-term effects on the musculoskeletal system (e.g., Ioannou et al., 2024).

Koch67_06
Kochevitsky seems to refer to AMCC for inter-joint force transfer by "the wrist and all other joints of transmission should be firmly set, to convey the needed energy to the keys", but this is uncertain.

Wolf72_01
The excerpt almost succeeds in scientific usage of "relaxation" and "tension" by contrasting the two, but concludes by describing "relaxed chord-playing" - strictly an impossibility given the scientific meaning of "relaxation" - and therefore obscuring the meaning of "tension" as well.

Tay79_01
There seems to be no evidence to support the idea that "opposing muscular tensions" (i.e., AMCC) make one "ten[d] to become shorter and narrower", apart from the compression that occurs between articular surfaces at the joint - which probably amounts to a few microns of shortening. A rudimentary exercise also casts doubt on the claim: keeping the hand and forearm still (e.g., on a tabletop), tightening the wrist via AMCC does not cause any appreciable shortening or narrowing.

Tay79_03, Tay79_04
It is not clear what Taylor means by "shortening", nor how it could occur via AMCC. It is also unclear what a "state of hypertension" entails in this case. Finally, Taylor incorrectly states that the "shortening of the arm cannot take place without the involuntary contraction of the neck and shoulder muscles". There does not seem to be a plausible definition of "shortening" that would validate this statement.

Tay79_07
The excerpt seems to imply a misunderstanding of functional anatomy. The '"expanding ' muscles…on the outside of the upper arm" seems to refer to the medial deltoid, which is responsible for the abduction ('expansion', reasonably enough) of the arm, up and to the side of the body. Given this, the '"contracting 'muscles" opposing the medial deltoid should be those responsible for adduction, the reverse of the abduction mentioned above; these adductor muscles include the pectoralis major, latissimus dorsi, and teres major, none of which can be found at Taylor's specified location: "the inside of the arm".

Fink92_01
Fink claims to have "established a precise vocabulary for writing this book that accurately describes" the topics within, at times "resort[ing] to technical terms to reduce ambiguity". Unfortunately, analysis of the work's following excerpts reveals this claim to be inaccurate itself.

Mans94_04
The anecdote about Cortot's book is interesting, given the concerns noted here with the same publication (see Cort28). While unlikely that Cortot would have been displeased

specifically due to these concerns, it seems plausible that his displeasure arose from a general dissatisfaction with the book, and a desire to forget or distance himself from it.

Ger07_36
Gerig misstates the nature and necessity of muscle dynamics that occur “when the finger strikes the key and reaches the key bed…in a coordinated movement”: he claims that “there is a corresponding reaction or relaxation in the antagonistic muscles. The greater the force applied to the key, the greater the amount of slack in the antagonistic muscles”. Firstly, there is no guarantee that a “corresponding reaction or relaxation in the antagonistic muscles” will occur. Secondly, it is strange to associate “reaction” and “relaxation” given they generally are two distinct phenomena. Thirdly, it is plainly incorrect to claim that “the greater the force applied to the key, the greater the amount of slack in the antagonistic muscles” - not only for the first reason, above, but even if such an event were guaranteed, the opposite reaction would be far more likely - increased tension in the antagonistic muscles, to dampen reactive forces from the finger-key interaction, thereby preventing undesirable displacement of the base.

Ger07_37
Gerig wrongly claims that “except for the softest levels of tone…there must be some fixation of the wrist joint” via AMCC; while such AMCC is typically desirable (even at the “softest levels of tone”), it is by no means an inevitability.

Fras11_64, Fras11_67
The excerpts are incorrect in regard to functional anatomy. Fraser’s claim that “upper arm contractions stabilize the hand” is misleading by omission - forearm contractions are first required to stabilize the hand - and transmit forces from upper arm contractions - before the upper arm can affect hand stability. Similarly, Fraser’s claim that “your hand’s structural security will not hold up without support from a fairly strong contraction of the triceps muscle group back in your upper arm” is false; depending on the movement, the triceps muscle group may be completely inactive yet the hand remains structurally secure (again, most likely due to forearm contractions). Moreover, the entire excerpt stands on shaky terminological ground given Fraser’s inconsistent usage of “contraction”.

Fras11_66
Fraser claims that “while grasping something with one hand…you can feel the contractions [of the triceps]” in the grasping arm - but this is easily disproven both via a correct understanding of functional anatomy (which demonstrates that hand-grasping is first controlled by forearm muscles, the added complication of upper arm muscles exercising indirect control being entirely optional) and also by simple self-experimentation: grasp an object while keeping the upper arm muscles relaxed (gentle grasping will prove to be a more robust demonstrator in this experiment, but firm grasping can also occur without upper arm activation) , and palpate the triceps with the inactive hand.

Fras11_92
Fraser suggests that a “liquefied”, non-“solid” state of the arm between triceps and knuckle allows the triceps to act “directly on your finger”, wrongly implying that muscular activity (including AMCC) is not required for this direct force transfer.

Fras11_106
Fraser intentionally writing “in direct contradiction” with himself about AMCC appears to be an attempt at expressing the complexity of the topic, but his intentional self-contradiction

instead prevents a deeper and more nuanced discussion of the phenomena being considered.

Aber13_01
It is not entirely clear what Abernethy means by “in opposition to each other”; in any case, “agonist and antagonist muscles” do “typically cocontract” for a variety of purposes, in varying contexts, which disagrees with the excerpt.

Rob14_03
The excerpt refers to many words that can relate to AMCC and muscle use (e.g., “resilience”, “elasticity”, “tension”, and “relaxation”) but defines none of them clearly.

Dea17_02
The excerpt is incorrect that “muscles must contract to stabilize the joints of the fingers, hand, and wrist…to produce a loud chord”; in fact, it is possible (though undesirable) to play a loud chord without such stability (e.g., by vertically stacking the joints and making a downwards thrusting motion into the desired keys). The excerpt also misstates functional anatomy by claiming that “if both the biceps…and the triceps…are activated to the same degree…the upper arm cannot move”. The biceps and triceps principally control the forearm in the elbow joint - exercising comparatively little control over the upper arm, unless in the unusual case of the forearm being immobilized (e.g., if a small child sits on an adult’s forearm). Moreover, even if the biceps and triceps are “activated to the same degree”, constituting isometric AMCC, the forearm can move, depending upon the relevant external forces (e.g., gravitational forces, perturbational forces from a handshake, etc.). In short, the excerpt is biomechanically flawed.

Assorted problematic examples, diagrams, models
Ort29_15
The excerpt presents a misleading and convoluted analysis of a hypothetical joint. Let us adopt the elbow joint as an illustrative example. Seemingly unintentionally, through use of the words “normal” and “norm”, Ortmann equates “pressure at the joint” and the “summated pull” of two antagonistic muscles - in our example, the pressure at the elbow joint and the summated pull of the biceps and triceps brachii. This is immediately problematic, because it conflates scalar and vector concepts: summated pull is scalar (e.g., 50 units of work from the biceps and 50 units of work from the triceps sum to 100 units of total work, a sum which would still remain even if the biceps had produced all 100 units of the work and the triceps 0, or vice versa), while joint pressure is a function of vector-based spatial geometry. Scalar measures cannot be accurately tied to joint pressure because they lack multidimensional geometry; in the above example (50 biceps units + 50 triceps units, versus 100 biceps units + 0 triceps units), the scalar sum is 100 in both cases - but the joint pressure is vastly different: 50 units of work from both biceps and triceps would result in 100 units of joint pressure, but 100 units from the biceps and 0 from the triceps would result in negligible (though nonzero) joint pressure, because the energy generated by the biceps would be converted primarily into joint torque (tangential force) at the elbow, causing flexion of the forearm, with the axial force contributing the negligible joint pressure. If we charitably interpret Ortmann’s “summated pull” specifically to mean a vector sum of axial pulling forces along the fibers and tendons of both biceps and triceps, the example becomes workable - but the analysis and understanding required to reach this charitable interpretation is burdensome and the excerpt best abandoned.

Ort29_16

The excerpted diagram and its corresponding discussion are of a particularly convoluted and questionable nature. We made a rough replica of the system represented in Ortmann's Figure 19 (see below) by suspending a wooden beam on a string and applying forces to the system that loosely corresponded in proportion and direction to those proposed in the excerpt. This produced results that were incompatible with Ortmann's proposed explanation, as we found that point "m" (the joint) moved in a lateral direction, creating an incompatible pull on scale A and seeming to disprove the claim that "m remains stationary" in the event of the varied forces described in the excerpt. This is not to say that the diagram is necessarily flawed, but moreso that the explanation is at minimum critically incomplete (point "m" not being specified as fixed in space or free, for example, and also whether the system is affected by gravity, and if so, in which direction is the gravitational pull), and therefore Ortmann's ensuing theoretical model of "hyper-, normla[sic], and hypo-relaxation" remains oddly mysterious.

Fig. 19, from Ortmann (1929), p. 61, and replica

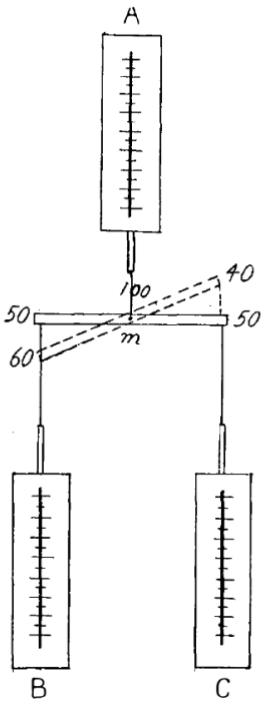
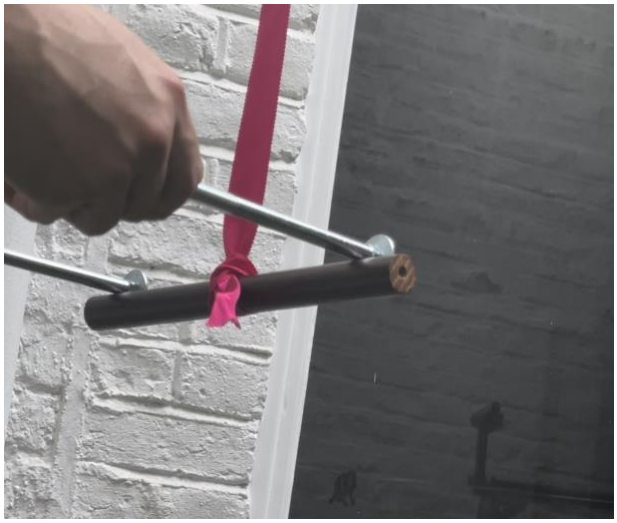


FIG. 19.



Ort29_17
Ortmann correctly identifies the “building of the keyboard in a straight line” as “opposed to curvilinear movement” and uses this as evidence of the “fallacy of ‘fixation’”, because “the more we attempt to restrict motion to one joint the more does the motion become curvilinear”. However, this neglects movements in the altitudinal and anteroposterior planes, including the centrally important movement of key-depression: the movement of each piano keys has a rotational (i.e., curvilinear) component around its center pin, implying at least the partial validity of a “fixation” theory that prohibits linear movements.

Ort29_18
Ortmann implies that the “hand-knuckle” should be “rigid” in order to act as a “fixed fulcrum” to “permit the finger-tip to exert its full force upon the key”, but this is inaccurate; for the hand-knuckle to act as a fixed fulcrum, it is the wrist joint that must be rigid (via AMCC) in order to immobilize the hand-knuckle in relation to the movements of the finger.

Ort29_39
Ortmann neglects the relevance of the angle of finger flexion when he claims that “the amount of fixation or muscular contraction necessary to do work at the finger-tip depends upon the positions of the parts of the arm”. For example, the two positions of fingers being held straight, as in a military salute, versus being flexed ~90° in the metacarpophalangeal joints, have significant effects on the amount of fixation or contraction necessary to do work, all else being equal. It is furthermore unclear which “bone” is intended by “longitudinal axis of the bone”, and finally confusing that “positions of the parts of the arm” is equated by implication with the directionality of “the resistance”, i.e., “at right angles” or contrastingly “parallel to this axis”.

Chi46_54
Ching wrongly claims that AMCC at the joint of movement “will be approximately the same whatever kind of touch we happen to employ”, given a steady tempo and rhythm. This neglects variables including dynamic level, articulation, and desired timbral quality - contradicting Ching’s prior acknowledgments thereof (e.g., Chi46_58).

Bon53_02
While not directly related to AMCC, it is worth critiquing the instructions for “Ideo-Kinetics” given that they imply a theory of piano playing that operates without characteristics of human movement that AMCC can assist in. This excerpt suggests an exercise that seems plainly impossible to perform successfully: if one performs even a single act “entirely foreign to the unity of the proposed experiment”, with closed eyes as instructed, then proprioceptive and locational awareness will be compromised to some degree, depending upon the act itself, and therefore it will not be possible to reliably “touch…the ball”. Throughout the work, Bonpensiere tends to design similarly tempting, but spurious activities.

Kay03_04
Figure 14 from the excerpt displays a “summarizing scheme of the kinematics and forces for a typical piano strike” in the arm, but does not display any pairs of antagonistic muscles and is therefore meaningfully incomplete.

Elasticity

While elasticity can broadly mean “the ability to change and adapt; adaptability” (OED), in mechanical or physical contexts it more specifically is a property that implies that a material or object “may be deformed and will return to its original configuration upon release of the deforming loads” (Soutas-Little, 1999, p. 66). This impending return to original configuration, in the context of joint movement, typically implies AMCC (Osu et al., 2002), so that preemptive (as opposed to reactive), dynamically adjusted antagonistic forces at a joint may swiftly recover the position of its corresponding limb segment after experiencing a temporary deformation (via displacement/perturbation).

Clear scientific definition

Ort25_01, Ort29_04, Ort29_50

Ortmann’s definition of elasticity parallels scientific usage. “[O]riginal size and shape” can additionally imply original position.

Cal03_13

Here Caland mentions the “highest state of firm, yet elastic tension”, implying that tension and elasticity can coexist - and the “highest state” of this tension in “the wrist” necessarily implies AMCC. This accords with scientific understanding of elasticity in biomechanical contexts. The word “yet” seems to falsely suggest a conflict between firmness and elasticity of this tension, but this is a minor quibble.

Stein05_22, Stein05_23

Riemann’s rejection of an equivalence between of “elasticity” and “pliability”, and his own definition of “elasticity” as “a body…[that] resumes its former shape with the same force with which it was compressed or stretched” clearly relates to the definition given by Soutas-Little, 1999, as do the examples of “steel, rubber, [and] whalebone hav[ing] considerable springing power; lead and clay, very little”.

Clear unscientific definition

Stein05_24

The excerpt claims that elasticity “has meaning only in a figurative sense”, which appears true in describing how the term is frequently used in pedagogical contexts, but is nevertheless undermined and contradicted by Steinhausen’s own referencing of Riemann’s scientific, practical definition immediately prior.

Unclear definition

Cal03_07

Caland equates “instantaneous relaxation, or yielding of the tension” with “a certain elasticity”, implying an unscientific usage of elasticity: biomechanically, AMCC (and therefore tension too) are what facilitate elastic joint behavior. Even though Caland lacks definitional clarity about “relaxation” and “tension”, prohibiting further understanding of her “elasticity”, we can still conclude by process of elimination that equating “yielding of the tension” with “a certain elasticity” is unscientific, because however she would specifically define tension, a “yielding” of it necessarily implies a reduction in contraction - therefore, a reduction in any AMCC - which opposes scientific understanding of joint elasticity.

Stein05_21

“[E]lastic forces” seems to be a misnomer, as it is material, not force, that exhibits elasticity (Soutas-Little, 1999). Regardless, the model makes it “quite clear where and how elastic forces occur”: AMCC in the relevant joints.

Stein05_25
The varying descriptions of elasticity here too seem to correspond with the model's finding of AMCC creating elasticity: "full of life up to the fingertips" seems to relate to AMCC's ability to enhance proprioception, while "yielding and at the same time ready to strike" could relate to AMCC's aiding reaction time, directional changes, and movement speed. Nevertheless, Steinhausen selects "[e]lasticity is only possible in the absence of any counterpressure" as "the best of the expressions" of elasticity - thereby choosing a definition that is both unscientific (as elasticity demands counterpressure in order to spring back from pressure-induced deformity) and also unclear (as it does not define elasticity but merely claims to describe conditions that allow for it).

Stein05_26
Steinhausen moves his focus to "elastic attack", critiquing this term as "nothing but self-deception" when it appears in pedagogy - but, the prior inconsistencies in Steinhausen's uses and critiques of "elastic" prohibit clear conclusions about "elastic attack" too.

Stein05_27
Now Steinhausen discusses "elastic effect" and "elastic powers", inaccurately claiming that "elastic powers…in the arm, hand and finger…cannot be varied or applied at will through some chosen form of movement" (when AMCC can indeed be considered a form of movement that can vary or apply elasticity at will).

Stein05_28
After belaboring his conviction that elasticity has no true meaning in pedagogy, Steinhausen strangely decides to offer a pedagogical quasi-definition of his own. He posits that all muscles around a joint are "in the same condition of…perpetual elastic tension", allowing "immediate effect…without stops and starts at the moment of contraction", and furthermore, "with the release of contraction" allowing the muscle to be "drawn immediately back to its original length". This account is specious - it mistakenly conflates tension and elasticity, attributes an imaginary passive, conserved springlike recoil to muscle tissue, and still offers no clear definition of elasticity (as opposed to "elastic tension").

Stein05_29
Now Steinhausen turns to "elastic activity", claiming "[f]rom the outside the elastic activity can be appraised only in the regularity and precision of movement", which is incorrect - elasticity can rather be assessed by the immediacy of the recoil movement, which has little to do with regularity and precision. Steinhausen continues that elastic activity is "distributed in…antagonistic and synergistic forces" - still vague, but closer to a scientific definition of elasticity in the context of human movement, given that AMCC helps to create joint elasticity.

Stein05_30
Here Steinhausen claims that terms like "suppleness, flexibility, yielding pose, etc.…<u>say nothing</u> physiologically and physically and…have nothing but a figurative connection with the term, elasticity". However, his critique of these terms' pedagogical use is unsubstantiated, much like his conclusion that elasticity is pedagogically meaningless (see e.g. Stein05_26). Steinhausen warns further that "any conclusion which is drawn from this sort of false concept and which does not keep strictly to scientific fact leads necessarily to a mistaken method that quickly produces confusion" - a reasonable critique, but one that can be applied principally to his own convoluted and unscientific account of elasticity (see

Stein05_28). This apparent hypocrisy is especially odd given Steinhausen's awareness of genuine, scientific definitions of elasticity (see Stein05_22 and Stein05_23): he references Riemann's accurate, scientific definition, yet does not reconcile this with his own definition and usage.

Rach13_01
Rachmaninoff does not define "elastic" beyond associating it with "clean, fluent, distinct" playing.

Hof20_01
Hofmann does not define "elasticity" despite making it a "chief point".

Matt32_08
Matthay does not define his "elastic steadying", apart from differentiating it from AMCC (although elastic joints in fact require AMCC).

Gat65_01
Gat begins with an unclear usage of "elastic". He clearly intends something unscientific, due to his claim that the body is "always in an elastic state when working", which precludes scientific usage - as elastic joints require AMCC, while "working" does not typically require AMCC.

Gat65_02
Gat clarifies that he believes a "hammer…rebound[s] elastically" after striking a nail; this implies an alternate, but correct meaning of elasticity to do with impact. The hammer and nail, both being quite inelastic materials, will undergo permanent deformations (e.g., the nail head will be slightly flattened, and the hammer head will gain a small dent where it struck the nail) - and will certainly not bounce back to their original shapes, as truly "elastic" (in the sense) materials would. However, even this correct, alternate scientific usage of elasticity is fleeting, as Gat then suggests that it is of "great importance in piano playing to use the feet as a means of elastic support" - implying a metaphorical usage of elastic that means neither material elasticity nor impact elasticity.

Gat65_06, Gat65_07, Gat65_08, Gat65_09, Gat65_18, Gat65_28
Gat does not provide further clarity regarding his intended meaning of "elasticity".

Koch67_04, Koch67_09
Kochevitsky does not define "elasticity", and incorrectly claims that there is no elasticity "either in the hand or in the piano key", instead explaining (e.g.) the phenomenon of rapid octaves played from the wrist as "a sensation that occurs according to the physiological law of reciprocal innervation, not according to the physical law of elasticity". In fact, the hand and keys both exhibit material elasticity, and in the former, this elasticity can be modulated via AMCC. Moreover, "reciprocal innervation" is an inappropriate explanation for this elastic behavior; it is more correct to describe this particular form of elasticity as muscular vibrato, which overrides reciprocal innervation, as a particular form of AMCC that lacks reciprocal characteristics.

Tay79_06
Taylor conflates "elasticity" with "springs" or "rubber" but appears not to have a clear definition of "elasticity", beyond the fact that it requires flexibility; otherwise, he might not have made the claim that "[elasticity] is an illusion…because the arms contain no springs, tendons are not made of rubber, and bones are totally inflexible" (emphasis added), as

elasticity can certainly exist in materials and objects apart from springs and rubber. Additionally, bones are not totally inflexible, as human bone is elastic (Smith and Walmsley, 1959). Finally, “the illusion that touch influences the quality of tone” had not “been exploded by modern scientific research” in 1979 nor has it now; on the contrary, modern scientific research has been conducted supporting the existence of this “illusion”, both in objective and subjective forms (e.g., Goebl et al., 2004; Ashkenazi, 2021).

Wat83_01
Waterman does not define “elastic support”, though she equates it to “flexibility”, which she contrasts with “stiff” and “tense”, and further associates “elastic support” with “not too yielding”.

Gri01_17
Grindea does not define “elastic” beyond associating it with “flexible”, which is also not defined.

Kay03_06
The authors imply a confusing usage of “passive elastic state of forearm muscles” by claiming this state is partly responsible for indirect hand movements initiated by muscles above the forearm - e.g., shaking the upper arm around while maintaining a relaxed wrist causes the hand to flop around. In fact, the elasticity of the forearm muscles has little to no bearing on this situation; instead, it is purely the “passive” state (rather than “passive elastic state”) of the forearm muscles that allow the hand to flop, as if those forearm muscles are active, i.e., stabilizing the wrist joint via AMCC, then the flopping of the hand is reduced commensurately to the degree of the AMCC - unless the AMCC is controlled dynamically to assist the hand-flopping rather than dampen it. The second usage, “forced elastic oscillations”, refers to the same hand-flopping with relaxed forearm muscles as above - but once again, a more precise description would simply be “forced oscillations”, as the elasticity of the wrist is actually lowest when the forearm muscles are relaxed - becoming more elastic in the alternative case described above: that the forearm AMCC crossing the wrist is controlled dynamically to assist the hand-flopping rather than dampen it.

Kay03_07
The authors’ use of “elastic” becomes increasingly problematic, as in continuing the example from Kay03_06, they suggest that static AMCC (here “statically active muscles of the forearm”) causes “conditions that are close to elastic oscillations in general” in the hand. This claim is doubly problematic: firstly, it contradicts Kay03_06, which suggested that “passive”, rather than “active” muscles of the forearm were responsible for the so-called “forced elastic oscillations” of the hand (this new, contradictory interpretation being correct, while Kay03_06’s claim was the incorrect one). This would appear to resolve one issue introduced by Kay03_06 - except for the authors’ use of the word “statically” to describe the forearm AMCC here. Static (i.e., unchanging over time) AMCC at the forearm implies reduced, not increased elasticity of the hand in the wrist, as either the hand would behave inelastically, ‘as a piece’ as if fused with the forearm, with the wrist completely resisting the “forced oscillations” resulting from upper-arm movement (if the static AMCC was sufficiently intense to resist the reactive forces applied from the upper-arm movement), or, the hand would behave somewhat elastically (but less elastically than if the AMCC were dynamic rather than static). In sum, the authors’ use of “elastic” is flawed in multiple ways.

Ger07_06

Liszt does not define “elasticity” here.

Ger07_13
Long’s definition of “elasticity” is not given here.

Ger07_26
Townsend’s definition of “elastic” is not given here.

Walk10_02
“Elasticity of the wrist” is not defined here.

Fras11_105
Fraser does not define “elastic” here.

Tension
In physics, “tension” is a scalar quantity defined as the magnitude of a force pulling away from an object (Serway and Jewett, 2008). More specifically, muscle tension can be defined as “the force generated by the contraction of a muscle”, which itself is a force pulling away from an object (Gordon et al., 2022, p. 372). Therefore, all muscle contraction (including AMCC) creates tension, and all active movement cannot occur without tension. In contrast, passive movement (any movement in a joint that is caused by any force external to the immediately adjacent muscles and the tendons that cross the joint - for example, being moved by another person’s actions, or, generating passive flopping movements in a relaxed wrist via undulating movements of the upper arm) can occur without local contractile tension.

Clear scientific definition
Stein05_01
The excerpt clearly and accurately defines tension in the context of sensations communicated by the nervous system (rather than mechanical tensions).

Field34_24
The excerpt equates “nervous tension” and “too much contraction”, implying an accurate usage of “tension” here, likely referring to excess tension due to music performance anxiety.

Field34_19
Contrasting “contracting” and “relaxing” is entirely correct.

Sch36_05
Schultz correctly contrasts “tension” and “relaxation”.

Chi46_02
Ching contrasts “tension” and “relaxation”, suggesting that “tension” is used for “activity (i.e., work), implying a clear scientific usage. Following excerpts from this work may be assumed to use the same definition, exceptions being documented accordingly.

Bow61_02, Bow61_03
Bowen contrasts “tension” with “relax[ation]”, paralleling scientific usage.

Kent76_08
Kentner implies a scientific usage of “tensing” by contrasting it with “relaxing”.

Bern81_04
Bernstein implies a scientific usage of “tension” by contrasting it with “relax[ation]”.

Obo07_01
Oborin uses “tension” scientifically by stating that “any movement is bound to involve tension in some muscle or other”, and that in contrast, “complete freedom is only possible in the absence of all movement, when everything is at rest…the whole of piano playing is in fact based on the rapid successive tensing and relaxing of muscles”.

Fras11_26
Here Fraser implies a scientific usage of “tension” by equating it with “muscular contraction”, which he also uses scientifically.

Fras11_33
Fraser implies scientific usage of “tension” by contrasting it with “relaxed”, which he also uses scientifically here.

Dea17_02
The excerpt implies scientific use of “tension” by observing that “muscle tension is necessary to create movement; playing the piano is impossible without muscular tension…muscles must contract to produce the energy for tone production”.

Dea17_03
It can safely be assumed that the authors continue their scientific meaning of “tension” here.

Clear unscientific definition
Stein05_41
If Rupert’s interpretation is correct, Steinhausen was incorrect in claiming that muscle tension necessarily produces movement.

Ort29_52
Here Ortmann implies a common unscientific usage of “tension” by equating it to “rigidity” and “stiffness”, and therefore to AMCC; while AMCC involves tension, so does all muscle activity (not only AMCC).

Field34_29, Field34_31
Here Fielden seems to intentionally and temporarily adopt the common unscientific usage of “tension”, for the purpose of critique, by equating it to “so-called stiffness” and therefore AMCC.

Chi46_13
Without warning, Ching changes his meaning of “tension” here from a standard scientific usage (see e.g. Chi46_02) to a clear unscientific usage - specifically, the common pedagogical usage of “tension” to mean specifically tension resulting from AMCC. The first clue for this change in usage is Ching’s instruction for “controlled playing of a single note by forearm touch”, which he advises “ought to be achieved by ‘freedom ’at the elbow joint, together with tension at the wrist”. “Forearm touch” requires movement of the forearm at the elbow joint - yet this is simultaneous with “freedom” in the same joint, while in contrast, “tension” occurs at the other joints. Therefore, by process of elimination, Ching here defines “freedom” as ‘one-sided contraction without AMCC’, as there is no other possible

meaning of “freedom” that supports simultaneous motion (thereby precluding true relaxation) and contrasts with a meaning of “tension” (thereby precluding AMCC, and additionally precluding true scientific usage of “tension” as well, as this usage is already occupied by “freedom”).

Chi46_14, Chi46_16, Chi46_17, Chi46_18, Chi46_19, Chi46_20, Chi46_21, Chi46_23, Chi46_24, Chi46_25, Chi46_26, Chi46_27, Chi46_28, Chi46_29, Chi46_30, etc.
Ching continues his clear unscientific usage of “tension” as meaning AMCC - e.g., “a state of tension” in order to cause “ joint…stabilisation”. No following exceptions to this usage were documented.

Tay79_02
Taylor adopts a clear, unscientific usage of “tensing” by suggesting that muscles “tens[e]” by “shortening the tendons to which they are attached”, but this is only partly correct; during eccentric loading (e.g., forearm flexion during AMCC at the elbow) a tense tendon is nevertheless lengthening (Widmaier et al., 2019), while tendons that are shortening may be in the process of relaxing (e.g., during asymmetrical relaxation of an isometric co-contraction).

Wins98_02, Wins98_03, Wins98_04, Wins98_05
The authors imply the common, unscientific, pedagogical usage of “tension” by equating “without tension” to “with alternating relaxation and contraction” - i.e., an absence of AMCC.

Con00_06
Now Conable provides a clear definition of “TENSION: n., ‘act of stretching or straining”. This clearly conflicts with scientific usage, the latter having no implication of “stretching” nor “straining”. Conable expands her definition to mean that “tension is tightening muscles and then using them”, in contrast to “work”, which means “using muscles”.

Mark04_01, Mark04_02, Mark04_04, Mark04_05, Mark04_06, Mark04_07
Here Mark defines “tension” as “excessive muscular work - work in excess of what is needed to accomplish the task at hand”, constituting a clear and idiosyncratic usage, which he contrasts with “free”.

Mark04_13
After self-contradiction and vagueness regarding the meaning of “tension”, Mark introduces a new contradictory usage by equating “tension” with “static muscular activity”.

Taub05_03, Taub05_05
The excerpt adopts the common, unscientific, pedagogical usage of “tension” to mean AMCC by asserting that “dual muscular pulls…is another name for tension”, and if “one muscle is active, and opposing muscle [is] passive…there is no tension”.

Unclear definition
Bach87_02
The excerpt’s description of the “rarest case” of “momentary tension” during the “snap 2” implies at minimum that tension is not relaxation, but a clearer definition of “tension” is absent.

Cal03_01, Cal03_04, Koch67_02, Koch67_08, Gies72_03, Gies72_14, Bern81_02, Bern81_05, Bern81_08, Bern81_09, Bern81_10, Bern81_11, Bern81_12, Bern81_13, Bern81_15, Bern81_16, Mar82_01, Mar82_02
The excerpts do not clearly define “tension”.

Cal03_07
Here Caland clarifies that “tension” is distinct from “stiffness or inflexibility”, and that “controlled ‘tension’…implies always the power of instantaneous relaxation, or yielding of the tension”. This suggests that Caland’s ‘tension ’is dynamic, rather than static, but reveals little else with certainty - for example, tension here could be either a unipolar contraction or a (bipolar) co-contraction, which are meaningfully distinct, yet not clarified here.

Cal03_10
Here Caland equates “removing tension” with “allowing [the] arm…to fall with unhesitating directness”; this could support a scientific usage of “tension” but could similarly support other definitions, remaining unclear.

Cal03_14
Here Caland equates a “lessening of all muscular tension” with “complete relaxation…[and] devitalization”; while this could support a scientific usage of “tension” and/or “relaxation”, it could similarly support other definitions- e.g., “tension” unscientifically meaning AMCC, and relaxation scientifically meaning “no contraction”, or, “tension” scientifically meaning “any contraction”, and relaxation unscientifically meaning “no AMCC”, etc. However, the qualifiers of “all” and “complete” imply at minimum the absence of AMCC.

Stein05_43
Rupert’s claim that Steinhausen equates conscious muscle selection and “tension” contradicts Steinhausen’s more accurate use of the term (see Stein05_01).

Stein05_50
It is not possible to assess Rupert’s judgment of Breithaupt because we know neither how Rupert nor Breithaupt define “tension” and “fixation”.

Hof20_03
Hofmann cautions against “holding the tension in your arm”, instead recommending to “transfer the display of force to the finger-tips”, but the transfer of this force from arm to finger-tips presupposes tension in the scientific sense. Therefore, Hofmann adopts an unscientific and moreover unclear definition of “tension”.

Hof20_05
Hofmann advises “hold[ing] arms and hands in but a slight tension” to play “rapid octaves”, which seems to refer to minimal AMCC supporting movement speed, but this is unclear as “tension” remains undefined.

Bac63_04, Bac63_06
Bacon does not define “tension” clearly, equating it to varied concepts such as “pull, virility, sinewiness, firmness, meaningfulness” - and contrasting it with “relaxation”, which does not clarify further given his inconsistent usage of “relaxation”.

D’Ab64_03

D’Abreu suggests a pedagogical usage of “tension” to mean AMCC, as in activity of both the “flexor and extensor muscles” simultaneously - but this does not preclude instead a scientific usage either, meaning that his usage remains unclear.

D’Ab64_05
D’Abreu’s definition of “tension” remains unclear; here he continues a habit of baseless, fallacious exaggeration with “it is common knowledge that…”.

Gat65_18, Gat65_30
Gat does not define “tension”, but it can at least be surmised that he does not intend the scientific usage - which is precluded by his instruction of playing with a “tension-free state of the body”.

Koch67_09
Kochevitsky seems to contrast “tension” with “relaxation”, tentatively implying a scientific usage, but this remains uncertain.

Lhév72_02
Lhévinne might imply a scientific usage of “tension” by equating “nervous tension” with “stiffening”, the latter which he defines as a state of inflexibility, but this is not conclusive.

Neuh73_01, Neuh73_08
Neuhaus does not define “tenseness” except by contrasting it with “relaxed” - but the latter he uses unclearly. Neuhaus also equates “tenseness” with “stiffness”, but stiffness too remains undefined.

Har80_01, Har80_02, Har80_03
Hargrave does not define “tension”. In any case, no form of “tension” will necessarily “always remain with the piano student unless constructive measures are taken to correct it”; the excerpt therefore exaggerates the necessity of these “constructive measures”.

Har80_06
Hargrave equates tension and stiffness, defining them both as “friction”. If “friction” is to mean friction between joint surfaces, then no plausible definition of either tension or stiffness would appear to validate this claim. Therefore, “friction” seems only to further reduce the definitional clarity of Hargrave’s writing. The analogy of the painter’s “stiff-haired brush”, in short, also does not make Hargrave’s intended points about piano technique clear.

Har80_13, Har80_15, Har80_16
It remains unclear how Hargrave defines “tension” beyond a similarity to “stiffness”.

Bern81_06
After previously adopting a scientific usage of “tension” (see Bern81_04), here Bernstein muddles the implied definition by claiming that “natural muscular tension is in itself a result of opposing forces-that of strength versus relaxation”. Even if strength and relaxation were “forces” in the scientific sense, tension would result from “strength” - not “relaxation”, and certainly not its opposition to “strength”.

Bern81_07
Bernstein continues to complicate his usage of “tension”. The “kind of tension” Bernstein claims to be “fully controllable, for it is a biological response to a resistance”, could also

occur involuntarily - not all adaptive motor behaviors are voluntary, just as not all maladaptive behaviors are involuntary. Otherwise, the challenge of developing and performing highly skilled motor behavior could be condensed to an issue of volition, when it in fact involves considerably more factors than this. Finally, it seems potentially contradictory that a “fully controllable” tension is also simultaneously “a biological response”, given how ‘biological ’is typically defined (“connected with the natural processes of living things”; Cambridge Dictionary, emphasis added). In sum, the excerpt falters due to terminological shortcomings.

Sán81_04
Sándor does not define “tensing” here, though it seems likely he intends a scientific usage. The excerpt also contains a fancifully unscientific critique of AMCC as “excessive discharges of the thyroid and adrenal glands”.

Tay81_02
Taylor does not define “tension” here, relating it to “fixation or contraction” - which implies either a scientific or common unscientific usage.

Arr82_02
Arrau implies two definitions of “tension” in the same paragraph - firstly suggesting a scientific meaning by contrasting it with “relaxation”, but soon contradicting this by suggesting that “piano playing” can occur “without getting physically tense”

Ohl82_01
Ohlsson does not define “tension” except by contrasting it with “relaxation”, which also remains undefined.

Phil82_01
Philipp does not define “tension”, but implies an unscientific usage.

Wat83_01
Waterman does not define “tense”, associating it with “stiff” - which she also does not define.

New84_04, New84_06
Newman does not define “tense”.

Fink92_03, Fink92_04, Fink92_05, Fink92_06, Fink92_12, Fink92_13, Fink92_23
Fink does not define “tension” but implies it might or might not occur during “the conscious use of one muscle group against another” - thereby suggesting a definition that is neither scientific nor the common pedagogical usage. Instead, he seems to mean a particular state of excessive exertion, related or equivalent to “fatigue” - but this is not clarified.

Fink92_07, Fink92_17, Fink92_25
Fink contrasts “overly tense” with “relaxed”, but the latter also remains undefined.

Dub93_01
Dubal does not define “tense”.

Mans94_03
Manshardt associates “tension” and “rigidity”, but defines neither, leaving room for both scientific and unscientific usages of “tension”.

List95_01, List95_02, List95_03
Lister-Sink does not define “muscle tension”, though she implies an unscientific usage by claiming that “it is possible to play…without accumulating ANY muscle tension at all”. She critiques “many within the medical community” who accept the “accumulation of muscle tension…as a natural byproduct of playing the piano”, which suggests either that she is unaware of the scientific definition of “tension” as it is typically employed by scientists, and instead interprets them to be in favor of a type of “tension” that she defines as undesirable, or that she intends an unusual meaning of “accumulation of tension” as ‘increase of static muscle tension without any release thereof ’- (or both) - but this is not clarified. Lister-Sink also claims that “it is possible to play in such a way that…muscles continually release their tension and refresh themselves”, but this is impossible if interpreted strictly and with a scientific usage of “tension”, because muscles cannot “continually” release tension in a given timeframe if they are to also accumulate (to use the standard meaning of accumulate, i.e., “gather together or acquire an increasing number of quantity of; gradually gather or acquire”; OED) the tension so that they may release it - which must occur during the same timeframe. Otherwise, the tension would be accumulated prior to playing the piano, in which case the act of playing the piano would entirely be one of muscular relaxation, with no new tensions generated at all - a clear absurdity.

Sher96_01, Sher96_04
Sherman does not define “tension”.

Bru97_01, Bru97_02, Bru97_04, Bru97_05, Bru97_06, Bru97_07, Bru97_10, Bru97_11, Bru97_14, Bru97_17
Bruser does not define “tension”. She likely intends the common, unscientific, pedagogical usage, but this not entirely clear. Speaking on behalf of “health professionals” without corroboration is questionable. Moreover, while technically correct that “the fingers themselves don’t have any muscles in them”, this does not imply, as Bruser believes, that it is incorrect to “exercise [finger] muscles and strengthen them”; it simply implies that the muscular hypertrophy occurs in the hand and arm. Moreover, tendons are strengthened by exercise (Kjær et al., 2006). Therefore, pointing out that the fingers “don’t have any muscles in them” is a pedantic irrelevancy, unless in response to someone claiming that muscles specifically inside the fingers would get stronger.

Ost97_02
Ostwald does not define Gould’s “extreme tension”.

Wins98_01
The excerpt does not define “tension”.

Wins98_06, Wins98_10
Grindea does not define any of “tension”, “positive tension”, or “negative tension”.

Wins98_11
Grindea declares that “The ‘Grindea technique’…liberat[es] the body of any tensions…not only the body but also the mind is free of tensions…”, contradicts her previous claim that “positive tension” is “essential for good performance” - and still not defining “tension”.

Con00_01

Conable does not define “tense”, contrasting it with a state of being “free”, which she advises should occur during “playing”. This seems to suggest the common, unscientific, pedagogical usage, but this is not conclusive.

Con00_03
Conable clarifies somewhat by claiming that “the muscles of your fanny…are shortened and narrowed by tension” - suggesting at minimum that “tension” implies contraction.

Sche00_03
Schenker does not define “tension”, suggesting the existence of a “tension of hand and arm position”, which implies at minimum an unscientific usage.

Tub00_03
The authors do not define “tension”, and misleadingly imply that it is a distinct “mechanis[m] of dynamic stabilization” from “contraction” when in fact tension is simply the result of contraction.

Gri01_02, Gri01_03, Gri01_04, Gri01_07, Gri01_08, Gri01_21
Grindea does not define “TENSION”. She contrasts it with “relaxation”, which also remains undefined.

Gri01_05
Grindea introduces the category of “negative tensions” without definition.

Gri01_06, Gri01_09, Gri01_10, Gri01_11, Gri01_13, Gri01_15
Grindea suggests a “balance of tension and relaxation”, contradicting Gri01_04, which claims that “the perfect state of balance of the body…is totally liberated of any tensions”, and “free of any tension” - the latter two quotations also excluding the possibility of a scientific usage. Grindea’s suggestion to “Release Tension” via “Downward and Upward Movements”, or through a “downward exertion”, also precludes a scientific usage.

Gri01_22
Given that Grindea’s every mention of “tension” in this work is unclear and/or unscientific, it is concerning that Grindea is “Founder and Chairman” of an “International Society of Tension in Performance” - which suggests at minimum that she actively promotes unclear and unscientific information about tension.

Lass01_01
Lasserson does not define “tension”, contrasting it with “relaxed”, but also not defining the latter.

Mark04_03
Mark muddles his clear unscientific use of “tension” to mean “excessive muscular work-work in excess of what is needed to accomplish the task at hand” (see Mark04_01) by describing some movements as being “completely tense”. This implies that some movements are achieved entirely by “work in excess of what is needed to accomplish the task” - which is impossible because here movement itself constitutes “the task” in question.

Mark04_08
Mark contradicts his earlier usage of “tension” as “excessive muscular work” (Mark04_01) by claiming that “if we fall into habits of imbalance, we must constantly use muscular tension to counteract the balance”; this counteraction via tension appears to represent a

non-“excessive” use of “tension”, as something that one “must” do is not excessive, but necessary.

Mark04_09, Mark04_10, Mark04_11, Mark04_12, Mark04_14, Mark04_21, Mark04_23, Mark04_24, Mark04_25, Mark04_27, Mark04_28, Mark04_29, Mark04_30, Mark04_37
It is now unclear as to what Mark means by “tense” due to self-contradictory, inconsistent usage (see Mark04_08, Mark04_13) and an absence of further clarification.

Mark04_16, Mark04_26
Mark provides some clarity by asserting that a joint may only “act as a fixed place…by tensing muscles” - perhaps suggesting either a scientific or common, unscientific, pedagogical meaning of “tensing”, but still inconclusively.

Mark04_34, Mark04_35
Here an unscientific (but still unclear) usage is indicated by Mark’s claim of playing “without tension, yet with…power”. Similarly, claiming that “movement is…not based on tensing muscles” clearly implies an unscientific (yet still uncertain) definition of “tensing”.

Sode06_01, Sode06_02
Thalberg does not define “tension” here, though implying at minimum an unscientific usage by claiming that playing can occur with the absence of “all tension”, and that “tension” contrasts with “extend[ing] and contract[ing] the fingers”.

Gold07_02
Goldenweiser does not define “tension”, contrasting it with “relaxed”, but not defining this either.

Ger07_02
Kalkbrenner does not define “tensions” here.

Ger07_04
Boissier does not define Liszt’s “tension” here.

Ger07_28
Gerig does not provide Matthay’s definition of “tension” here.

Ger07_49
Gerig leaves room for either scientific or common, unscientific, pedagogical usage of “tension levles” by observing that they are controlled by “functioning of the various pairs of antagonistic muscles”.

Kent07_01
Kentner does not define “tension” - contrasting it with “relaxation”, which remains undefined.

Perl07_01
Perlemuter does not define “tension” - contrasting it with “supple”, which also is undefined.

Sher07_02, Sher07_03
Sherman does not define “tension” - contrasting it with “relaxation”, which remains undefined.

Bol07_01
Bolet does not define “tension”.

Vás07_01
Vásáry does not define “tension” here, associating it with “stiffness” and “relaxation”, which also remain undefined.

Wild07_01, Wild07_02
Wild does not define “tension”, associating it with “tightness” and contrasting it with “flexible”, which remain undefined.

True07_01
True does not define “tension”, nor “positive tension”, and contradictorily advises “total freedom…from any tension” yet claiming that “on the other hand positive tension is vital”.

Ohl07_01
Ohlsson does not define “tension” - contrasting it with “relaxation”, which remains undefined.

Fras11_04, Fras11_06, Fras11_11, Fras11_19
Fraser does not define “tension” here - contrasting it with “relaxation”, which remains undefined.

Fras11_20
Fraser vaguely connects “tension” with AMCC (“dual muscular pull”) - which is somewhat clearer, but it is still uncertain whether he intends a scientific or common, unscientific, pedagogical meaning of “tension”.

Fras11_31, Fras11_47, Fras11_55, Fras11_62, Fras11_65, Fras11_68, Fras11_71, Fras11_73, Fras11_85, Fras11_93, Fras11_96, Fras11_107, Fras11_109
Given Fraser’s inconsistent use of “tension” throughout the work, it is not clear what he means by “tension” here.

Wall13_01, Wall13_02
Wallick does not define “tension” here, making his brief comparative history of “tension” in pedagogy misleading and flawed by equating its usage across pedagogues such as Dorothy Taubman and Seymour Bernstein. In fact, Taubman adopts a clear unscientific usage of “tension” to mean AMCC (see e.g. Taub05_03), while Bernstein’s usage varies (see e.g. Bern81_04, Bern81_06, Bern81_07) - yet never overlaps with Taubman’s.

Karp14_01
Medtner’s definition of “tension” is not given here.

Stan14_02
Stannard does not define “tension”. Furthermore, there does not appear to be evidence supporting the claim that “stretching to extremes will force…opposing muscles to act against each other”; nor would this necessarily constitute “unnecessary tension”.

List18_01
Lister-Sink does not define “tension”, though suggesting an unscientific use at minimum by implying that tension may or may not occur during “continuous contraction”.

Kou20_01
Koumis does not define “tension”.

Relaxation
In biomechanical contexts, “relaxation” refers to the absence (or cessation) of muscle activity - beginning with the motor neurons, which stop releasing signals to the muscle, enacting a complex biochemical process that quickly results in the muscle fibers losing their ability to generate tension (Gordon et al., 2022). In healthy muscle tissue, contraction and relaxation alternate perpetually and temporally inconsistently - no muscle remaining permanently in a state of total relaxation nor maximal contraction. Therefore, while “relaxed” muscle implies the total absence of contraction, a “relaxing” muscle implies a muscle that is currently releasing a prior state of contraction, either partly or completely - meaning that a “relaxing” muscle is by definition not “relaxed”, because a “relaxed” muscle is not in a state of contraction, and therefore cannot be made to “relax” any further. In contrast, “relaxation” can refer either to the state of being relaxed or also to the process of relaxing - which again is mutually exclusive with the state of being fully relaxed.

Clear scientific definition
Stein05_07
The excerpt equates “relaxation” with “passivity” and “rest in the muscles”, according with scientific usage.

Stein05_34
The excerpt contrasts “[c]ontraction and relaxation”, equating “relaxation” with “passivity…and lack of contraction”, paralleling scientific usage.

Stein05_44
The excerpt accurately equates “relaxation” with “muscles [being] lax”.

Matt11_02
The excerpt indirectly reveals scientific usage of “relaxation”, connecting it to the cessation of “effort”, and “support” via “muscles”.

Matt14_03
Matthay equates “relaxation” with “passiv[ity]”, corresponding to scientific usage.

Ort29_09
The excerpt contrasts “contracted” and “relaxed”, paralleling scientific usage.

Ort29_20
Clear scientific usage can safely be assumed due to Ortmann’s consistent prior usage thereof (see e.g. Ort29_09).

Field34_10
Fielden equates “relaxation” with “a relaxing, dismissing, process”; dismissal of muscle activity qualifies as a clear scientific usage of “relaxation”.

Field34_16
Equating “release of the muscles” with “relaxation” is entirely correct.

Field34_19, Field34_24
Contrasting “contracting” and “relaxing” is entirely correct.

Field34_39
It appears that the excerpt continues Fielden's scientific usage of "relaxation".

Schm35_03
The excerpt correctly equates relaxation with passivity, "neither extended nor forcefully flexed".

Schm35_04, Schm35_05, Schm35_06, Schm35_07, Schm35_09, Schm35_10
The excerpts can be safely assumed to continue Schmitz's clear scientific usage of "relaxation".

Schm35_13
The excerpt continues Schmitz's clear scientific usage of "relaxation", but does not contribute further to the present discussion regarding AMCC.

Sch36_04, Sch36_05
Schultz correctly contrasts "contraction" and "relaxation".

Sch36_13, etc.
The excerpts may safely be assumed to continue Schultz's clear scientific usage of "relaxation". Any exceptions are documented here.

Chi46_02
Ching suggests that "relaxation" contrasts with "tension" and represents "inactivity", demonstrating clear scientific usage. Following excerpts from this work may be assumed to use the same definition, exceptions being documented here.

Bon53_03
Bonpensiere's equating of "relaxed" with "full rest" parallels scientific usage.

Harr53_01
Harrison's contrasting of "relaxation" with "effort" parallels scientific usage, though somewhat loosely. However, while it seems reasonable that "we sometimes say things which are not scientifically exact…because they convey our ideas more forcefully and picturesquely", it would appear even more reasonable, in such teaching situations, simply to make the forceful, picturesque statement and include a disclaimer of its scientific inaccuracy. Particularly when dealing with topics frequently discussed inaccurately (e.g., AMCC), anything less than clarity is dangerous.

Bolt54_01
Bolton contrasts "relaxation" with "exertion", according with scientific usage.

Bow61_01, Bow61_02, Bow61_03
Bowen contrasts "relaxed" with "causing muscles to operate", and with "tension", paralleling scientific usage.

Whi61_02
Whiteside refers to "Webster's definition" of "relax" as "to make lax or loose"; this broadly accords with scientific usage.

Bac63_02

Bacon clarifies by contrasting “relaxation” with “operation” of the arm and hand, implying scientific usage of “relaxation” to mean an absence of activity.

D’Ab64_03
Here D’Abreu clarifies by discussing “partia[l]” relaxation with simultaneous “muscular effort”, versus “complet[e]” relaxation. This suggests a clear scientific usage - contrasting with D’Ab64_01 and D’Ab64_02.

Gat65_04, Gat65_18
Gat implies a scientific usage of “relaxed” by contrasting “absolutely relaxed” with the “imperceptible” antagonist activity due to “muscle tonus”.

Gat65_22
Gat’s continued scientific usage of “relaxed” can be surmised because he contrasts this state with “contraction”.

Koch67_01, Koch67_09
Kochevitsky implies a scientific usage of “relaxations” by alternating them with “contractions”.

Gies72_01
The excerpt loosely implies a scientific usage of “relaxed” by equating it to the “natural position of the hand” - i.e., the position of the hand at rest.

Lhév72_02
Lhévinne correctly observes that a “completely relaxed” arm will “do nothing but flop limply at the side”, implying a scientific usage of “relaxed” to mean ‘inactive’.

Kent76_02, Kent76_03
Kentner now implies a scientific usage of “relaxed” as “[at] rest”, moreover contrasting it with “contract” and “active”.

Kent76_08
Kentner returns to a scientific usage of “relaxing” by contrasting it with “tensing”.

Last80_03
Last implies a scientific usage of “relax” by observing that relaxing the ‘“up ’muscles” will cause the arm to “fall downward”, and in contrast, “reassert[ing]” these muscles would “arres[t]” the arm. However, Last80_02 claims that the shoulder “should never be relaxed”; does this therefore imply that the shoulder is always “needed for the job of the moment”? If so, then the instruction to “relax…any muscles not needed for the job of the moment” is not particularly enlightening.

Bern81_04
Bernstein implies a scientific usage of “relax” by contrasting it with “contrac[t]”.

Sán81_02, Sán81_06
Sándor implies a scientific usage of “relaxes” by contrasting it with “works”, “muscular activity”, and “contraction”.

Tay81_01, Tay81_05

Taylor implies scientific usage of “relaxed” by relating it to a ‘“free ’fall of the arm”, also describing a “partially relaxed” fall that is “controlled”.

New84_03
Newman implies a scientific usage of “relax” by relating ‘“relax ’completely” to “utter limpness”.

Wins98_02, Wins98_05
The authors imply a scientific usage of “relaxation” by contrasting it with “contraction”.

Sche00_02, Sche00_03
Here Schenker implies a scientific usage of “relaxed” by observing that in a “relaxed state”, the “shoulder, elbow, and wrist…remain in the natural position according to gravity”.

Tub00_01
The authors imply a scientific usage of “relaxing” by contrasting it with “contracting”. However, “each muscle alternates relaxing and contracting with the other” is potentially unclear, as it sounds perhaps opposed to AMCC. Additionally, AMCC has additional purposes beyond acting as a “breaking[sic] mechanism”, which is not necessarily its primary function; it is unclear why the authors chose to highlight this particular function of AMCC at the expense of others.

Obo07_01
Oborin adopts the scientific usage of “relaxing” by associating it with “complete freedom…the absence of all movement, when everything is at rest”, contrasting this with “tensing”, which he also uses scientifically.

Ger07_09
Gerig implies a scientific use of “relaxation” by contrasting it with “contraction”, which he also appears to use scientifically.

Ger07_12
The excerpt’s use of “relaxation” appears consistent with Lhévinne’s earlier scientific usage (e.g. Lhév72_02).

Ger07_14
Long implies a scientific usage of “relax” by equating it with “let go” and noting that it is “contrary to the action of playing the piano”.

Ger07_23, Ger07_24, Ger07_33, Ger07_36, Ger07_41, Ger07_49
The excerpts may safely be assumed to continue Gerig’s scientific use of “relaxation” from Ger07_09.

Fras11_31, Fras11_103
Here Fraser implies a scientific meaning of “relaxation” by observing that “total relaxation…equals total inactivity”, being “totally limp”.

Kou20_03, Kou20_04
Koumis implies a scientific use of “relax” by contrasting it with “us[ing] our muscles”, “tightness”, and “stiffness”.

Kou20_05, Kou20_06, Kou20_07, Kou20_08

The excerpts can safely be assumed to continue Koumis 'scientific meaning of "relax".

Clear unscientific definition
Matt11_02
Matthay's three definitions of "relaxation" (1: no AMCC; 2: playing with free-falling weight; 3: immediate cessation of contraction at the moment of tone emission) are all clear unscientific usages.

Stein05_48
Rupert acknowledges the scientific definition of "relaxation" indirectly by noting that it would "lead, obviously, to the production of no sound at all…joints would be limp and the arm would fall back to the side". However, Rupert continues by claiming that an alternative understanding of "relaxation" is preferable: specifically, as "elimination of all muscular action not directly contributing to the action and a conscious use of weight and swinging mass in the production of tone". This alternative, unscientific definition appears to be intended by many pedagogues. It is a problematic definition because it necessarily blurs the boundary between true relaxation and partial relaxation - with no proposal of a further term to describe the concept of true relaxation, both states (true relaxation, and 'directly contributory' contractions only) cannot be clearly distinguished from one another.

Stein05_57
Similarly as in Stein05_48, Rupert acknowledges the scientific definition of "relaxation" and then scoffs at its usage in pedagogy - here by Schultz. Rupert continues by reiterating his alternative definition from Stein05_48, claiming that this is "the root of all good technique" and uncharitably accusing Schultz of an "essential ignorance". Unfortunately, because Rupert's definition of relaxation contains a key flaw, prohibiting the differentiation of true relaxation and selective muscular economy, it cannot be the "root of all good technique".

Pau13_01
The excerpt indirectly reveals a clear unscientific usage of "relaxation" meaning "undesired, excessive relaxation" - through the metaphors of "flabby looseness" and "spineless caterpillars".

Ort29_55
Ortmann strangely departs from his prior consistent,(scientific usage here, discussing "relaxed movement" (implying an unscientific usage) and making this usage clear by contrasting it with "excess rigidity" (meaning AMCC); movement with relaxation and without AMCC can only mean one-sided, unipolar contraction, a common and unscientific pedagogical meaning of "relaxation".

Field34_29, Field34_31
Fielden here seems to temporarily adopt a common pedagogical meaning of "relaxation" for the purpose of critiquing it - wherein "relaxation" means avoidance of "tension" (similarly defined here as in the common pedagogical usage 'absence of AMCC').

Cov48_01
Coviello correctly identifies one of Matthay's usages of "relaxation" (see Matt11_02).

Bow61_05
Bowen implies a shift in the meaning of "relaxation" without warning - previously using it in the scientific sense (e.g. Bow61_02), but here simultaneously recommending

“movements” and a “relaxed condition” in the same joint - which is only possible if he has now adopted the common pedagogical usage of “relaxation” to mean “movement without AMCC”.

Bac63_04
Bacon clarifies that “relaxation” means that “all muscular tensions, save those needed at the moment, should be released”, adding that “relaxation is not supineness”. This implies a clear unscientific usage of “relaxation” as ‘minimal necessary contraction’. This definition commits a conceptual fallacy in its defense of “relaxation” as the release of “all muscular tensions, save those needed at the moment”. In other words, Bacon claims that ‘relaxation ’means ‘relaxed muscles, except for those that shouldn’t relax’; this is definitionally inoperable, as it is clearly possible to relax muscles that should not relax. Holding a glass of water and relaxing the hand and finger muscles will allow the glass to tumble to the floor - regardless of the desirability of the ensuing mess.

Brux72_02
Bruxner delivers a clear unscientific definition of “relaxation ’as “loose and unrestricted”; in reality, a relaxed muscle nevertheless is neither loose nor unrestricted, likely maintaining both baseline tension from muscle tone and passive stiffness from connective tissues - both precluding looseness and lack of restriction.

Tay79_02
Taylor adopts a clear, unscientific usage of “relaxation” by suggesting that “relaxing” means “allowing the tendons to lengthen”. This neglects the possibility of isometric relaxation, in which agonist and antagonist relax equally and simultaneously, so that no change of tendon length occurs. Moreover, muscle relaxation is typically considered a passive process rather than a “perform[e]d…function” - but as seen here, it is not uncommon for pedagogues to improperly invest a certain ‘activity ’in relaxation.

Fink92_11
Here Fink associates “relaxing” with “lengthening” - a clear, unscientific usage, given that true relaxation can also occur during shortening (and in converse, contraction can occur during lengthening) - e.g., by co-contracting agonist and antagonist equally and then relaxing (or contracting) each at varied rates.

Ger07_16
Carreño provides a clear but unworkable definition of “relaxation” as “to loosen just where it is needed and nowhere else”; this is self-defeating because it implies that unneeded relaxation is not relaxation.

Unclear definition
Dir97_01
It is clear that Diruta does not adopt the scientific definition, as he suggests “keep[ing] the hand relaxed” while “slap[ping]” and “caress[ing]”. Therefore, Diruta either intended the common pedagogical definition (movement without AMCC) or something else entirely.

Dir97_02
Crozier wrote her translation of Diruta in 1941; given that Diruta’s definition of “relaxation” is uncertain (see Dir97_01), it seems that Crozier’s extension of this “relaxation” into “organ playing today” is moot.

Dir97_03

Because Diruta's definition of "relaxed" is unclear, we cannot draw firm conclusions about his proposed relationship between relaxation and "agility".

Bach87_01, Bach87_02, Cal03_05, Cal03_06
Similarly as in Dir97_01.

Cal03_14
See Cal03_14 elsewhere.

Cal03_15
"[R]elax" here is contrasted with "contract", which could support a scientific usage - but "contract" remains undefined (see Cal03_15 elsewhere), prohibiting firm conclusions.

Stein05_38, Stein05_39
Here Steinhausen incorrectly equates a "relaxed muscular condition" with "the minimum of necessary muscle action", and similarly, connects a" passive relaxed condition" with a "slight impulse on the labile arm mass". Steinhausen muddles things further by adding that ideal motions "must have relaxation as passive weighting". This is despite his earlier, correct usage of "relaxation" (e.g. Stein05_07, Stein05_34).

Stein05_45
It is not clear what Rupert means by Steinhausen's "passive position"; regardless, Steinhausen is correct in relating passivity and relaxation, so Rupert's suggestion of abandoning the "passive position" to develop an "almost irrefutable theory in regard to relaxation" appears false.

Stein05_51
Given Rupert's varying usages of "relaxation" (see Stein05_044 and Stein05_48), it is not possible to determine whether his judgment is correct that "Matthay…can be placed with Breithaupt and Steinhausen as one of the so-called relaxation exponents".

Stein05_60
Rupert seems inaccurate in equating the positions of Matthay, Schultz, and Steinhausen on relaxation (all three having differing ideas and positions on this) and moreover inaccurate in equating their positions on ideomotor theory and reinvestment, i.e., "relating muscular action to artistic expression"; at minimum both Schultz and Matthay advise extensive training that contradicts the principle that Rupert claims they uphold.

Matt11_01
Matthay does not explain what it means for "arm-weight" to be "relaxed"; presumably, he means that the muscles that act upon the arm are to be relaxed, so that the weight of the arm can drop freely in space, but this is not clear.

Gab13_02
Similarly as in Dir97_01. Also, it is unclear how Gabrilowitsch differentiates "arm" and "shoulder", given his claim that shoulder activity allows his arm to be "completely relaxed".

God13_01, God13_02, Hutch13_01
Similarly as in Dir97_01.

Cort28_04

Similarly as in Dir97_04. Furthermore, it is difficult to imagine a definition of “relaxing” that would validate Cortot’s false claim that playing extra notes in stretching exercises would have the “salutary effect of relaxing the muscles of the fingers”.

Matt32_15
Matthay does not define “relaxation” here; he probably intends his first definition from Matt11_02: movement without AMCC.

Field34_01, Field34_02, Field34_03, Field34_04, Field34_05, Field34_06
Fielden does not define relaxation here. “conscious contraction before relaxation” tempts a scientific definition, by contrasting contraction and relaxation, but the use of “conscious” muddies this significantly; unconscious contraction would still be appropriately contrasted with relaxation.

Sch36_17
The testimony of a “great pianist” that “during a recital his arm is completely relaxed from shoulder to finger-tip” reveals a nonscientific meaning of “relaxation” used by the “great pianist” - a point which Schultz seems to have missed, as the latter’s claim here is that the “great pianist” clearly cannot accurately perceive his own muscular activity. This is possible, but could only be confirmed if Schultz had conclusively determined the “great pianist”’s intended definition of “relaxed” - which remains unspecified.

Bow61_06
After switching from clear scientific to clear unscientific usage, Bowen now muddles “relaxation” further by discussing “weight which starts relaxing from the shoulder”, which is incompatible with both of his earlier definitions and moreover unclear.

Bac63_01
Bacon uses “relaxation” vaguely, leaving room for either a scientific or unscientific usage.

Bac63_05
It appears that Bacon contradict’s Casals ’meaning of “relaxation” - the latter clearly implying the common pedagogical usage (movement without AMCC) by recommending “the conscious practice of relaxation” while performing a “concert”, and the former implying a scientific usage of “relaxation” as a “release [of] effort”. In either case, the argument that “relaxation” is “conducive to good hearing” and “beneficial to complete control” is not made strongly here.

Bac63_06
Bacon still does not clarify a clear definition of “relaxation” - he does contrast it with “tension” but leaves “tension” vaguely defined too.

Bac63_07
Here Bacon equates “relaxed” with “limp” - seeming to imply a scientific usage, except that he advises this limpness to occur in an “exploring hand”, indicating limpness during movement - an impossibility unless “limp” too has a nonstandard definition.

D’Ab64_01, D’Ab64_02
D’Abreu does not define “relaxation” clearly. Connecting it to “feel[ing] completely inert”, while also connecting it to “successful co-ordination”, implies that he intends a subjective muscular state that is ‘relaxed ’in neither the scientific nor common pedagogical fashion.

This is aside from the difficulty of judging relaxation by eye, and moreover the hyperbolic, false claim that “experiment has proved beyond doubt” the importance of “relaxation”.

D’Ab64_04, D’Ab64_05, D’Ab64_06
Despite clear scientific usage of “relaxation” in D’Ab64_03, dozens of pages have since passed; this, and the author’s general terminological inconsistency, imply that we should not assume a particular definition of “relaxation” here.

Gat65_07, Gat65_08, Gat65_10
Gat implies a new meaning of “relaxation” without warning by discussing a “relaxed and elastic state” of the “whole body” during playing, implying a simultaneity of relaxation and activity in the whole body - which contradicts his prior, scientific usage (see Gat65_04).

Gat65_15, Gat65_26, Gat65_28, Gat65_30
Given Gat’s two contrasting meanings of “relax”, we cannot conclusively determine his meaning here.

Brux72_01
Bruxner does not define “relaxed recovery”.

Gies72_04, Gies72_05, Gies72_06, Gies72_07, Gies72_08, Gies72_09, Gies72_10, Gies72_14
The excerpts do not define “relaxation” but implies it occurs during “movements” - suggesting at minimum an unscientific usage, apparently contradicting Gies72_01.

Wolf72_02, Wolf72_03
Wolf does not define “relaxation”, but implies at minimum an unscientific usage by claiming that it occurs simultaneously with being “active”.

Neuh73_01, Neuh73_04
Neuhaus does not define “relaxed”. He contrasts it with “tenseness”, which he uses unclearly. He also equates “completely relaxed” with “no contraction” - which would seem to imply a scientific usage of both, except that he claims that this must occur during “playing” - therefore precluding scientific usage of “relaxed” and furthermore prohibiting transitively defining “no contraction” and subsequently “contraction”.

Kent76_01
Kentner does not yet define “relax”.

Kent76_07
After clear scientific usage of relaxed (see Kent76_02 and Kent76_03), Kentner now regresses to an unclear usage by suggesting a simultaneity of being “relaxed” and performing a “movement” in the “arm and…hand”.

Har80_04
Hargrave equates “relaxed” with the “absence of stiffness”, but does not define “stiffness” clearly.

Har80_05, Har80_07
Hargrave suggests that relaxation should persist widely during playing and simultaneously with “hold[ing] the shoulders back” - implying an unscientific usage, but otherwise remaining unclear.

Har80_08
The excerpt contrasts “relaxed” and “fir[m]”, providing a degree of clarity about Hargrave’s intended meaning of “relaxed”, but this remains inconclusive. The excerpt also distinguishes “relaxed arm weight” and “dead arm weight”, which might suggest Hargrave intends the pedagogical definition of “relaxed” (i.e., movement without AMCC) rather than the scientific usage (which would imply “relaxed arm weight” being more similar than contrasting to “dead arm weight”). The suggestion to “hang on the keys…by the fingertips only” also does not clarify what Hargrave means by “firmness”, as one can “hang on the keys” with varying muscular strategies.

Har80_09
Here Hargrave either misunderstands functional anatomy or implies a new, contradictory meaning of “relaxed”, by claiming that “the arch of the hand…may be somewhat relaxed simultaneously with a degree of firmness still held in the fingers”. In fact, this firmness requires activity of muscles and/or tendons passing across the midpoint of the arch of the hand - given any plausible definition of “firmness” - which would equate firmness and relaxation, while Hargrave previously contrasted them (Har80_08).

Har80_10
Similarly as in Har80_09, Hargrave either misunderstands functional anatomy or equates firmness and relaxation, by suggesting to “rela[x] every part of the playing mechanism…simultaneously holding the fingers and arches firm”.

Har80_11
Hargrave now implies that “relaxation” and “firmness” are opposite ends of a scale, as he recommends a “degree of firmness” such that “the degree of relaxation” is not “excessive”. This does not accord with his earlier usage (e.g., Har80_10).

Har80_12, Har80_14, Har80_17, Har80_19
It remains unclear what Hargrave means by “relaxed”. It also seems unlikely that anyone (including Hargrave) has “acquired consummate muscular coordination and flexibility” and has “never…been subject to physical disturbances or even common fatigue”.

Har80_20
Hargrave relates “relaxation” and “flexibility”- still providing no clear definition of either.

Last80_01, Last80_02
Last does not define “relaxation”, and while her claim that Matthay equated “relaxation” and “freedom” seems true (see Matt11_02 and Matt14_22, this only represents one of at least three definitions explicitly adopted by Matthay.

Bern81_01, Bern81_02
Bernstein does not define “relaxation” here.

Bern81_05
Bernstein muddles his usage of “relaxation” further. If assuming the continuation of his scientific usage of “relax” in Bern81_04, it is an impossibility to “relax your muscles” when “lift[ing] a heavy suitcase”. In fact, as it is not possible to perform a physical act (i.e., lifting a suitcase) with all muscles relaxed, this would wrongly suggest that non-action itself causes “back trouble”. The intended point appears to be: ‘if you relax the wrong muscles while lifting a suitcase, you could harm yourself’, which is a more reasonable claim - but given the

passage as written, this interpretation relies on a self-defeating definition of “relax your muscles” as ‘relax the wrong muscles’, implying that relaxing the right muscles would be relaxing the wrong muscles.

Bern81_09, Bern81_11, Bern81_12
Bernstein does not clarify his meaning of “relax” here.

Arr82_01, Arr82_02
Arrau does not clarify “relaxed” - implying at minimum an unscientific usage by claiming its simultaneity in the shoulder with being “used”.

Dar82_01, Dar82_02
Darré does not define “relaxed”, despite its apparent “importan[ce]”.

Ohl82_01
Ohlsson does not define “relaxation” except by contrasting it with “tension”, which also remains undefined.

Mar82_01
Marcus does not define “relaxed”, though she relates it to “flexibility” and “resilience”, adding that it is found “in the malleability and pliability of the [joints]”. She also suggests that “relaxation” occurs during playing - in contrast to “looseness, which doesn’t project anything”. Nonetheless, a precise definition remains out of reach.

Rod82_01
Rodriguez does not define “relaxation” except by contrasting it to “precis[ion]”.

Phil82_02
Philipp does not define “relaxed”.

Schi82_01, Schi82_02
Schick does not define “relaxed”, though a scientific usage seems likely.

Wat83_01
Waterman does not define “relaxed”, contrasting it with “tense” - which she also does not define.

God89_01
Godowsky does not define “relaxed”.

Fink92_02, Fink92_05, Fink92_08, Fink92_21, Fink92_23
Fink does not define “relaxation”.

Fink92_07, Fink92_17, Fink92_18
Fink associates “relaxed” with “not overly tense”, but the latter is also not defined.

Fink92_09, Fink92_14, Fink92_15, Fink92_16, Fink92_24, Fink92_25, Fink92_26, Fink92_27, Fink92_28, Fink92_29, Fink92_31
Fink now suggests that “relax” occurs simultaneously with “movements”, or “go[ing]”, or being the “strongest” in the same joint or limb - implying an unscientific but still unclear meaning of “relax”.

Fink92_10
Fink now implies another unscientific, unclear usage of “relax” by giving an example that is impossible given scientific usage: “sitting spinal extension is encouraged by relaxing…[the] lower back” and “simultaneously contract[ing] your lower abdominal muscles”. Spinal extension is accomplished by contraction of the very “lower back” muscles that Fink seeks to relax, and is moreover antagonised by the “lower abdominal muscles” that Fink seeks to contract.

Mans94_01, Mans94_03
Manshardt does not define “relaxation”.

Bru97_02, Bru97_03, Bru97_12
Bruser does not define “relaxation” except by contrasting it with “tight muscles” and associating it with being “loose”, both of which can themselves have multiple meanings. It is also unclear whether she intends the common, unscientific, pedagogical usage of “relaxation”. Furthermore, apparently no evidence supports the excerpt’s pseudoscientific ideas about a relaxed body as a “resonating chamber for the sound produced by the instrument”.

Bru97_04, Bru97_09, Bru97_13, Bru97_18, Bru97_19
Bruser implies at minimum an unscientific usage of “relax” by suggesting that “practice time…is a time to…let your body relax”, or that the “hands…[may] relax” during “grasping”, or similarly, that the arms may “relax” during “movement” - for example, the forearm may be “relaxed…during rotation”.

Bru97_11, Bru97_14
Bruser still does not define “relaxed”; she contrasts it with “tension” but does not define this either.

Bru97_15, Bru97_16
Bruser’s statement that “relaxing the tip of the thumb relaxes the muscular co-contraction in the wrist and forearm” does not clarify what she means by “relax”; even by overlooking her misstatements here (principally, that the “tip of the thumb” is something that can be relaxed to begin with), there remains room for either a scientific or unscientific usage.

Ost97_01
Ostwald does not define Gould’s “one single, relaxed unit” of the hand.

Wins98_04
The excerpt does not define “relaxed”, though the common, unscientific, pedagogical usage seems most likely.

Wins98_07, Wins98_08, Wins98_09
Grindea does not define “relaxed”.

Con00_04
Conable does not define “relaxed”, but her description of “relaxed and efficient motor activity” suggests the common, unscientific, pedagogical usage.

Sche00_01
Schenker does not define “relaxed”, contrasting it with “rigi[d]”, which leaves room for multiple meanings.

Tub00_06
After clear scientific usage (see Tub00_01), the authors imply a different, unclear, unscientific meaning by advising a “relaxed…posture” that is simultaneously “upright”.

Gri01_06, Gri01_07, Gri01_08, Gri01_09, Gri01_10, Gri01_11, Gri01_12, Gri01_13, Gri01_14, Gri01_15, Gri01_16, Gri01_17, Gri01_19, Gri01_20
Grindea does not define “relaxation” except by contrasting it with “tension”, which she also does not define. This could support a scientific usage - except that she advises simultaneous “relax[ation]” with movement, e.g., “send[ing] the relaxed arms”.

Lass01_01, Lass01_02, Lass01_03
Lasserson does not define “relaxed” except by contrasting it with “tension”. Her recommendation of “relax[ation]” during “play[ing] octaves” precludes scientific usage.

Ger07_19
Leonard’s definition of “relaxed” is not provided here.

Mark04_09
Mark does not define “relaxed” except by associating it with “free”.

Sode06_02
Thalberg associates “relaxed” and “supple”, in contrast to “tension” - but defines none of these.

Gold07_02
Goldenweiser does not define “relaxed”, contrasting it with “tension”, but not defining this either.

Ger07_05
Liszt’s definition of “relaxed” is not given here. His recommendation of remaining “relaxed” during playing precludes scientific usage.

Ger07_15
Debussy’s definition of “relaxation” is not provided here.

Ger07_17
Breithaupt’s definition (if any) of “relaxation” is not given.

Ger07_20
Leonard does not define “relaxed”. His observation of remaining “relaxed” during a handshake precludes scientific usage.

Ger07_21
It is not clear whether Breithaupt is truly unaware of the “fallacy” described here, or if he alternatively simply used a different definition of “relaxed”.

Ger07_22, Ger07_23, Ger07_38
Gerig does not discuss whether and/or how Breithaupt defines “relaxed”.

Ger07_35

In an apparent oversight, Gerig contradicts his previously consistent, scientific usage of “relaxed” by describing that “simple flexion at the elbow…is not a relaxed movement” due to its requirement of involvement of the “antagonistic pronating muscles” - this implies that without AMCC, Gerig would consider the movement to be “relaxed” - which precludes a scientific usage.

Kent07_01
Kentner does not define “relaxation” - contrasting it with “tension”, which remains undefined.

Sher07_02, Sher07_03
Sherman does not define “relaxation” - contrasting it with “tension”, which remains undefined.

GerGrin07_01
Gerig does not define “relax” here; see Ger07 for Gerig’s mostly consistent scientific usage of relaxation.

Vás07_01
Vásáry does not define “relaxation” here, contrasting it with “stiffness” and “tension”, which also remain undefined.

Lill07_01
Lill does not define “relaxation”, though he implies a nonscientific use at minimum.

Smi07_01
Smith does not define “relaxation”.

Wild07_01
Wild does not define “relaxation", though he implies a nonscientific use at minimum.

Ohl07_01
Ohlsson does not define “relaxation” - contrasting it with “tension”, which remains undefined.

Fras11_01, Fras11_04, Fras11_05, Fras11_06, Fras11_07, Fras11_13, Fras11_18, Fras11_27, Fras11_28, Fras11_29, Fras11_30, Fras11_33, Fras11_34, Fras11_35, Fras11_36, Fras11_44, Fras11_45, Fras11_49, Fras11_56, Fras11_57, Fras11_58, Fras11_62, Fras11_63, Fras11_75, Fras11_82, Fras11_94, Fras11_99, Fras11_100, Fras11_101, Fras11_104, Fras11_107
Fraser does not define “relaxation”. He seems to imply a shifting usage, relating both to physical and psychological definitions, but these are not individually clarified either. His usage of “relaxation” also is frequently unscientific and even self-contradictory - e.g., in claiming that “Arrau’s relaxation allows a naturally vivacious enervation of the finger muscles”, “vivacious” and “enervated” reasonably being defined antonymically - or, by claiming that “movements can be relaxed”.

Wall13_01
Wallick contrasts “relaxed” with “tension”, defining neither.

Rob14_02, Rob14_04
Roberts does not define “relaxed” here.

Stan14_01
Stannard does not define “relaxation”, claiming that “it is what happens in the wake of correct physical action”.

Fixation
In human movement contexts, “fixation” typically refers to the practice of orthopedic implantation to improve function in joint disorders and injuries (Farjam et al., 2022); for example, the coraco-clavicular Bosworth screw, which is implanted to artificially rejoin the clavicle and coracoid process of the scapula after acute acromioclavicular joint disruption, effectively reconstructing the joint (McConnell et al., 2007). This usage has little relevance to the meaning of “fixation” in piano pedagogy, and there does not appear to be an established alternative usage (e.g., in biomechanics literature) that would be a more appropriate comparator to pedagogical fixation. Therefore, I proceed to adopt a loose standard definition of “fixation” as “the action or process of fixing or being fixed” (OED). This requires a further definition, for “fixed”: “fastened [maintained] securely in position” (OED).

Clear standard definition
Ort29_17
Ortmann implies “fixation” means “restrict[ing] motion to one joint”, i.e. by immobilizing the other nearby joints; this parallels the OED’s usage.

Ort29_18
Here Ortmann describes the “hand-knuckle fixed as a fulcrum”, implying a contextual usage of “fixed” to mean “immobilized in relation to the finger lever”, which fits comfortably within standard usage.

Ort29_19
The excerpt relates “lack of motion” and “fix[ing]…position”, clearly paralleling standard usage.

Ort29_21
The excerpt can safely be assumed to continue Ortmann’s consistent, clear, and standard usage of “fixation”.

Ort29_35
After prolonged departure from standard usage, Ortmann unexpectedly resumes standard usage of “fixation”, equating it with “held in position”.

Ort29_51
After even further inconsistency, Ortmann returns to a clear standard usage of “fixation” to mean “fixing of the position” of joints. Given this usage, the excerpt’s claims are incorrect (similarly to Ort29_36 and Ort29_37).
Matt32_02, Matt32_03
The excerpts qualify for clear, standard usage by equating “fixation” with being “stable and immobile”.

Mark04_16, Mark04_17, Mark04_18, Mark04_19, Mark04_20, Mark04_22, Mark04_26, Mark04_36
Mark associates “fixed” with being “stable” as a “fixed place” - clearly connecting the term to positional stasis. He is moreover justified in suggesting that the “general assertion that

any bodily motion requires a fixed or stable place to move from" is incorrect (see e.g. New84_01).

Taub05_04
The excerpt adopts a standard usage of "fixed" in the sense of "a fixed point from which to move", implying positional stasis. However, the excerpt advises that "we always have to have a fixed point from which to move", contradicting Taub05_02, which demonized "fixating the arm" by comparing it to the undesirable, fatiguing situation of "five racing-horses pulling along a train without an engine".
Taub05_05
The excerpt appears to continue standard usage of "fixed".

Ger07_04
Boissier implies standard usage of "fixed" in the sense of "no definite fixed position" when describing Liszt's hands.

Clear non-standard definition
Ort29_27, Ort29_28, Ort29_32
Here Ortmann strangely departs from his earlier usage of "fixation" without warning, by implying an equivalence between "sufficiently rigid" to "transmi[t]…weight", and "fixed". This suggests that fixation requires rigidity via AMCC, but this is not necessarily true; fixation can be achieved without AMCC (for example, via one-sided contraction against an external resistance - which includes the act of quiet standing). Therefore, Ortmann's usage of "fixation" is no longer consistent by this point in the text. Similarly, he claims that "relative fixation…is necessary to permit the force to act at the desired point", extending his change in usage, and claiming that during an arm descent, the hand "became fixed just before key-contact", further reinforcing this conflicting usage.

Ort29_36, Ort29_37, Ort29_38, Ort29_39
Having briefly returned to standard usage (see Ort29_35), Ortmann seems to once again use nonstandard usage of "fixation", relating it to "overcom[ing] the weight of the intervening [body] parts".

Ort29_42
Ortmann muddles "fixing" even further, using it here to mean the prevention of a reactive movement in a joint ("fixing the wrist against over-extension") - a joint that is fixed neither positionally nor in regard to AMCC (his two prior meanings).

Ort29_53
Ortmann now returns to his second definition of "fixation", relating it to "transmit[ting] force", the absence of "give", and therefore implying AMCC and stiffness or rigidity.

Matt32_07, Matt32_08, Matt32_09, Matt32_10, Matt32_16
After his earlier clear, standard usage, Matthay strangely uses "fixing" in an alternative manner by equating it to "stiffening" (which he consistently uses to mean AMCC); this implies a clear nonstandard usage of "fixing" to mean "stiffening" and "using AMCC". Similarly, he equates "Fixation" with "Tug-of-war derived from the simultaneous exertion of antagonistic or 'contrary 'muscles".

Field34_14, Field34_15
After prolonged unclear usage, Fielden adopts a clear nonstandard usage by equating a "fixed" hand with a "rigid" hand that is "'of a piece' with the forearm". This is the common

nonstandard usage of “fixed” to mean AMCC - which is here implied by the combination of “rigid” and “of a piece”, which can only be achieved by AMCC (barring external, artificial supports like splints or casts; see e.g. Sharma & Venkadesan, 2021). However, Fielden improperly conflates the “hand” being “rigid” with the “hand” being “‘of a piece' with the forearm”; this confuses the site of fixation (the hand) with the origin of the fixation (AMCC across the wrist, originating in the forearm). Therefore, for the “hand” to be “‘of a piece’ with the forearm”, the hand may or may not be rigid, so long as the wrist and parts of the forearm are rigid.

Field34_38
Fielden returns to a clear nonstandard usage of “fixation” here by connecting “strong fixation” to a “strong, all-inclusive muscular and nervous impulse” - which implies fixation being equivalent to AMCC.

Field34_39
Fielden seems to extend his immediately prior, nonstandard usage of “fixation” to mean AMCC by equating “flexible fixation” with an “anchorage” that “has been mistaken for relaxation” by some pedagogues.

Sch36_02
Schultz implies a common nonstandard definition of “fixed” as equivalent to AMCC (“contract[ing] the biceps and triceps muscles simultaneously”).

Sch36_13, Sch36_14, Sch36_15, Sch36_16 Sch36_18
The excerpts may safely be assumed to continue Schultz’s nonstandard usage of a “fixed” joint to mean a joint experiencing a state of AMCC. Any exceptions are documented here.

Gat65_22, Gat65_23, Gat65_24, Gat65_29
Gat implies the common nonstandard use of “fixed” to mean a state of AMCC, by equating it with “simultaneous contraction”.

Sán81_08
Sándor implies the common nonstandard use of “fixed” to mean a state of AMCC, equating it with “antagonistic”, “simultaneou[s]…contraction”.

Kay03_05
The authors indirectly imply a nonstandard meaning of “fixation” as akin to the effects of AMCC - by suggesting that wrist fixation may “increase” during “wrist motion”.

Mark04_05, Mark04_06
Now Mark equates “fixed” with “tense”, the latter which he defines as being in a state of “excessive muscular work” (see Mark04_01).

Ger07_07, Ger07_11, Ger07_27, Ger07_28, Ger07_29
Gerig does not define “fixations” explicitly, but it is clear that he intends the common, nonstandard, pedagogical usage, meaning AMCC - e.g., by claiming that Deppe retained “a desirable degree of hand and arm fixation” while playing, and by describing “muscular fixation”, both descriptions which preclude the scientific usage. This interpretation is further corroborated by his description of Matthay as having the “fear that fixation will inevitably lead to undesirable tension” - given we know that Matthay is diametrically opposed to AMCC (see e.g. Matt08_01).

Ger07_30
Gerig finally provides a definition of “fixation” as “simultaneous contraction”, supporting the above (see e.g. Ger07_07).

Ger07_32, Ger07_33, Ger07_37, Ger07_38, Ger07_41, Ger07_42, Ger07_44, Ger07_45, Ger07_46, Ger07_47
It can be safely assumed that the excerpts continue Gerig’s nonstandard usage of “fixation” as AMCC (see Ger07_30).

Fras11_23
Here Fraser adopts a clear nonstandard usage of “fixation” to mean AMCC, asserting that “fixation [is] caused by two opposing muscle groups working purposefully one against the other”.

Fras11_25
It appears that Fraser continues his nonstandard use of “fixation” here.

Unclear definition
Stein05_06
Steinhausen does not define “fix”, so “do not hold back or fix anxiously” cannot be firmly interpreted, beyond concluding that fixation contrasts in some way with holding back.

Stein05_08
Steinhausen still does not define “fix”, making it impossible to firmly interpret how “to fix” equals “to exclude and to make ineffective…muscles”. In any case, the definition must be non-standard, as in the standard sense, joint fixation includes muscles and makes effective use of them, depending on intent and task demands.

Stein05_13
While the example of “fixation of the upper arm by means of a book held fast between it and the ribs” provides some clarity, Steinhausen still does not provide a clear definition of “fixation”, while claiming “there is still much to be done in the step-by-step battle to free the body from all sorts of fixations”.

Stein05_14
Here Steinhausen’s “fixation” becomes more murky again, as he relates it to “muscles which pull the shoulder blades down…tension through arbitrary lowering or fixing of the shoulder”; is Steinhausen’s idea of “fixation” now a one-sided static contraction? It remains unclear.

Stein05_15
Now “fixation” to Steinhausen is caused by “stiffness”, but he does not define the latter, extending terminological uncertainty.

Stein05_17
The excerpt relates “extreme fixation” to a “certain degree of muscular tension”, but it is still unclear whether Steinhausen uses “fixation” to mean e.g. AMCC or a positional fixation or something else. The excerpt also commits an argumentum ad populum fallacy.

Stein05_18
The excerpt relates “flexib[ility]” to “allow[ing] fixation to occur only as far as it is necessary”, but this still allows varying interpretations of “fixation”.

Stein05_19
Here Steinhausen the absence of “fix[ation]” to a state wherein “everything is movable”; this suggests that he intends a meaning of positional immobility, but this is inconsistent with earlier excerpts (especially Stein05_08) and therefore inconclusive evidence.

Stein05_33
Steinhausen’s “elimination of all fixation” cannot be clearly interpreted because “fixation” continues to lack a definition.

Stein05_37
Steinhausen’s cautioning against “mak[ing] the chain tensed and fixed”, “conscious fixation”, and “internally fix[ing]” the wrist cannot be clearly interpreted because “fixation” continues to lack a definition.

Stein05_46
The excerpt seems to correctly relate AMCC with joint stability, but because Rupert does not define “fixation”, this remains uncertain.

Stein05_52, Stein05_53
Because Rupert does not define “fixation”, we cannot firmly interpret his judgments of Schultz and Matthay.

Stein05_56
Rupert seems to misinterpret Schultz’s definition of “fixation” as meaning “restriction of movement”, thereby misinterpreting Schultz broadly..

Stein05_58
Here Rupert seems to better understand Schultz’s meaning of “fixation”, but now misunderstands the distinction between individual finger independence versus fingers being isolated from the arm via wrist fixation (which seems to be what Schultz actually meant). Therefore, Rupert’s point about “unequal” finger muscles, while true, appears irrelevant.

Stein05_59
Rupert continues to critique Schultz without providing an explicit definition of “fixation”; here, it is unclear whether Rupert is referring to a “contra-fixation touch” in the sense of finger fixation or finger movement against a base of wrist fixation - and therefore, the discussion of a “sensation of pressure in the finger”, which according to Rupert “leads inevitably to the tensing of the extensor muscles in the fingers”, cannot be interpreted firmly - leaving open the possibility of both Schultz and/or Rupert being incorrect on multiple counts. Rupert also suggests erroneously that extensor muscles exist “in the fingers”, a common mistake (he probably meant those that control the fingers extrinsically).

Matt08_09
It is unclear what Matthay means by “fixed” here - is it positionally fixed (not requiring AMCC), or muscularly fixed (equivalent to AMCC) (or both)?

Ort29_29
Given Ortmann’s descent into inconsistency regarding the meaning of “fixation”, it is not possible to determine which of his prior meanings is intended here - either proper, contextual usage (i.e. Ort29_18), or incorrect usage (i.e., Ort29_27, Ort29_28).

Ort29_43
Having convoluted “fixation” into three clear and distinct meanings, Ortmann here uses the term with an unclear meaning. Depending on the meaning of “fixation”, this excerpt seems additionally to contradict earlier excerpts regarding the effects of AMCC on accuracy. For example, Ortmann suggests that AMCC aids “very fine degrees of coördinated movement” in Ort29_22, but here implies the opposite- that “fixation will…interfere with the accuracy of the movement” if it occurs in the joint “in which movement actually takes place”. There is no indication that Ortmann is talking about different levels of AMCC - for example, it would not be contradictory to suggest that excessive AMCC would interfere with movement accuracy, but the excerpt and context both do not appear to suggest this.

Ort29_51
The intended meaning of “fixation” remains unclear here.

Field34_05
Fielden does not define “fixation” here.

Field34_09, Field34_10, Field34_11, Field34_12, Field34_13
Fielden still does not define “fixation”, but relates it to a nonstandard, common usage by connecting it to “support[ing] the blow” and “bear[ing] the strain”, i.e., equating fixation to AMCC for joint stability. This usage seems even more likely through fixation “as a buffer to withstand the impact”, but fixation “as an anchorage” sounds more like the standard usage.

Field34_18, Field34_20
After adopting a clear nonstandard usage for a time, Fielden returns to an unclear usage, relating “controlled fixation” as the “absence of…loose and free” movement and a lack of “gradual relaxation”. This can support multiple meanings of “fixation”.

Field34_25
Fielden extends his unclear usage of “fixation” by categorizing it as either “nervous or muscular”, claiming this is connoted by extreme muscular contraction, “the minimum of muscular control”, and also the “elimination of muscular vibration by nervous control” - conflicting and vague concepts.

Field34_30, Field34_33
Fielden continues unclear usage of “fixation”, relating it to “a state of contraction”, and “balance between contraction and relaxation” - most likely referring to optimal, dynamic AMCC, but this is not entirely certain.

Field34_37
Fielden extends unclear usage of “fixation” by contrasting it with “relaxation”, leaving room for multiple interpretations. It seems he intends it to mean some form of AMCC, as he thinks it is related to “agility…[t]idiness, and lack of brilliancy and clearness”.

Gies72_10, Gies72_11, Gies72_12, Gies72_13
The excerpts do not define “fixation” except by equating it to “rigidity” - which also remains undefined.

Gies72_15, Gies72_16, Gies72_17, Gies72_18, Gies72_19, Gies72_20

The excerpt suggests “fixation” is mutually exclusive with “intensive active efficiency”, and also contrasts with “relaxing” - but this does not provide sufficient clarity. The excerpts also contradict each other by advising both for and against fixation.

Kent76_04, Kent76_05, Kent76_06
Kentner does not define “fixation”, but claims that it relates to multijoint force transfer (which is accomplished by AMCC, suggesting a common nonstandard use).

Sán81_01, Sán81_05
Sándor does not define “fixing” here.

Tay81_02, Tay81_03, Tay81_04, Tay81_05
Taylor equates “fixation” to “contraction” and “firmness”, defining none of these.

Schi82_03
Schick relates “fixed” and “firm”, defining neither.

New84_01
Newman does not define “fix”, though he likely intends a scientific usage, meaning immobilized “sufficiently to withstand the lever actions” (and also reactions). However, given this meaning, he is mistaken that “eventually some base somewhere along the line must be fixed enough to enable the lever to strike”. While it may indeed be disadvantageous not to perform such fixations, as this will result in inefficient movements and uncontrolled perturbations, it is by no means necessary in order to play a single note or even multiple notes.

Gri01_20
Grindea does not define the “point of fixation”, though suggests it occurs in the wrists by “thrusting” - which does not clarify her meaning.

Mark04_03, Mark04_15
Mark associates “fixed” and “stiff”, defining neither.

Taub05_02
The authors do not define “fixating”.

Ger07_18, Ger07_22, Ger07_24, Ger07_25, Ger07_31
Gerig does not reveal whether and/or how Breithaupt and Fielden defined “fixation” (see Field34 for a thorough analysis of the latter’s usage of “fixation”).

Fras11_42
Despite previous clear usage of “fixation” to mean AMCC (see Fras11_23 and Fras11_25), here Fraser implies a conflicting meaning of “fixing the structure” as “making it solid” - a solidity which is only approximated by maximal AMCC, which even then cannot make a joint truly “solid”.

Fras11_51, Fras11_52, Fras11_59, Fras11_60, Fras11_61, Fras11_74, Fras11_80, Fras11_88, Fras11_95
Due to Fraser’s inconsistent prior usage of “fixation”, we cannot conclusively determine his meaning here.

Rob14_04

Roberts does not define “fixation” here, contrasting it with “complete relaxation”, which also remains undefined.

Dea17_01
The excerpt associates “stabilized” and “fixated”, defining neither; a joint stabilized by AMCC may nevertheless not be in a state of fixation (e.g., the elbow can be stabilized by contraction of the upper arm muscles while simultaneously being moved by a movement of the upper arm in the glenohumeral joint).

Dea17_05
The authors describe a “fixed base of movement” and differentiate this with a “moving base”, providing no clarity to the intended meaning of “fixed”.

Rigidity
In biomechanical contexts, rigidity can be considered a quantifiable material property, equivalent to viscoelastic stiffness and related to mechanical impedance (Patrick et al., 2001; Stanev and Moustakas, 2019). The more rigid a joint, the more it resists displacement, requiring a larger force in order for movement to occur. Rigidity can occur passively (e.g. in Parkinson’s disease, as documented in Sepehri et al., 2007), or actively, principally via AMCC (Nagai et al., 2012). A residual amount of passive rigidity is also implied by muscle tone.

In pedagogical contexts, rigidity often carries a negative connotation, similarly as in the case of stiffness - often because the intended pedagogical definition of “rigidity” typically is “rigidity in excess of what is desirable for playing well” (as will shortly become clear below).

Clear scientific definition
Matt14_01, Matt14_10
Matthay correctly observes that AMCC (“opposite exertion…with the required one”) can cause “rigidity”.

Ort25_02, Ort29_02
Ortmann’s definition of rigidity as the “property of matter permitting its shape to be changed only by a great force” and in the case of muscle, “a contraction preventing motion among the parts of the body” is largely accurate. It is slightly imprecise to refer to bodily rigidity as the muscle contractions themselves - more accurately, rigidity arises in the body often due to contractions, but it is a distinct concept from contraction. This distinction is minor and does not disqualify Ortmann’s usage. Notably, “rigidity” is the only key term relating to AMCC that Ortmann uses with total consistency.

Ort29_03
Ortmann’s definition of plasticity as “the opposite of rigidity”, and “that property of matter which permits it to be moulded into various forms”, accords with scientific usage for both terms.

Ort29_08
Ortmann’s division of rigidity into passive and active types is entirely correct.

Ort29_09
Ortmann’s claim that “the degree of rigidity depends upon the degree of simultaneous contraction” is entirely correct.

Ort29_11, Ort29_18, Ort29_26, Ort29_27, Ort29_41, Ort29_44, Ort29_47, Ort29_52, Ort29_55, Ort29_56
These excerpts can safely be assumed to extend Ortmann's earlier, consistently clear and scientific usage of "rigidity". Notably, "rigidity" is the only key term relating to AMCC that Ortmann uses with total consistency.

Matt32_13
Matthay achieves a clear scientific usage of "rigidity" by equating it with "stiffness".

Field34_14
Fielden indirectly makes a clear scientific usage of "rigid" by equating it to being '"of a piece 'with" in the context of the hand and forearm; this clearly suggests the correct equivalence of "rigid" joints with the presence of AMCC that locks together adjacent limb segments by stiffening a joint.

Gat65_22
Gat uses "rigid" in the scientific sense by equating it to "fixed", which he defines unscientifically as being in a state of AMCC via "simultaneous contraction".

Krau82_01
Kraus does not define "rigid" here.

Ger07_04
Liszt implies a scientific usage of "rigid" by contrasting it with having "a certain 'give'", which is suggestive of nonrigidity - willingness to move.

Ger07_33
Gerig implies a scientific usage of "rigid" by contrasting it with "too much relaxation" ("relaxation" being used scientifically) and associating it with "joint fixation" (being used here to mean AMCC).

Fras11_23
Fraser implies a scientific usage of "rigidity" by equating it to "stiff", the latter which he also uses scientifically.

Clear unscientific definition
Bow61_06
Bowen implies a meaning of "rigid" as excessively stiff due to AMCC - being held too "firmly", and being "unyielding", in contrast to "thick rubber", which is "flexible".

Gat65_23
Gat dilutes somewhat the clear scientific usage of "rigid" from Gat65_22 by now comparing "rigidity" to "excessive tightening" - meaning excessive rather than any AMCC. This is similar to the usage in Bow61_06 and appears to represent a common unscientific pedagogical definition of "rigid".

Bru97_08
Bruser makes a clear, unscientific usage of "rigid" by equating a "rigid posture" to one that is "static", i.e., unmoving.

Mark04_36

Mark associates “rigid” with “fixed”, the latter which he uses in the standard sense; this indicates a clear, unscientific usage of “rigid” to mean positionally immobile.

Unclear definition
Cal03_07
Caland equates “[r]igidity” with “stiffness” and “inflexibility”, but does not define either of these. It therefore remains uncertain whether Caland’s “rigidity” and “stiffness” refer moreso to (e.g.) excessive contraction of any kind, or, particularly static contractions, or, both.

Stein05_55
It is not clear whether Steinhausen is in favor of any “rigidity”, given his opposition to both fixation and stiffness (see Stein05_08 and Stein05_12), and given that the other excerpts of Steinhausen do not discuss “rigidity”.

Matt08_12
Matthay does not define “rigidly” except by contrasting it to “perfectly ‘free ’and loose”, leaving room for multiple interpretations.

Gab13_01, Krau81_01, New84_04
The excerpts do not define “rigid”.

Gies72_10
The excerpt does not define “rigidity” except by equating it to “quite a strong fixation”, which also remains undefined.

Lhév72_04
The excerpt does not define “rigidity” except by contrasting it with “loose”.

Last80_04
Last does not define “rigid” except by contrasting it with “flabby”.

Mans94_03
Manshardt does not define “rigidity” except by associating it with “tension”, leaving room for multiple interpretations.

Con00_02
Conable does not define “rigid” apart from arbitrarily judging that it is “not beautiful”, suggesting a simplistic aesthetic view.

Sche00_01
Schenker does not define “rigidity”, contrasting it with being “relaxed”, which leaves room for multiple meanings.

Ger07_08
Mason does not define “rigidity” except by associating it with “hardness” or “stiffness”, which he also does not define. He contrasts it with “stability, strength, repose”, but this does not make a definition clear.

Walk10_01
Boekelmann does not define “rigid in mind and body”, though Walker associates it with “great physical expense”, loosely suggesting a nonscientific usage.

Fras11_15, Fras11_40
Fraser does not define “rigidity”, equating it to “convulsiveness”, and contrasting “totally rigid” with “solid”.

Fras11_41, Fras11_43
Here Fraser associates “rigid” with “stiff” - the latter which he uses unclearly as well.

Fras11_48, Fras11_72, Fras11_73, Fras11_80, Fras11_90, Fras11_91, Fras11_95, Fras11_97, Fras11_104, Fras11_108
Given Fraser’s inconsistent usage of “rigid”, it cannot be determined here what he means by “rigid”.

Dea17_01, Dea17_02
The authors do not define “rigidity”, conflating it with “stiffness”, which is also undefined. A further association with “fixation” (also undefined) is not enlightening.

Stiffness
In biomechanical contexts, stiffness can be considered equivalent to rigidity (see above), a quantitative measure of how much a limb resists displacement at a joint - related to mechanical impedance (Patrick et al., 2001; Stanev and Moustakas, 2019). The more stiff a joint, the more its corresponding limb segments resist movement in the same joint (Rouse et al., 2012). For example, a maximally stiff wrist will prevent either the hand or forearm from moving in relation to one another without extreme force; however, both hand and forearm may still be moving in space together despite this wrist stiffness, due to (e.g.) a raising or lowering of the entire arm in the glenohumeral joint. Similarly as in the case of rigidity, some residual stiffness occurs due to muscle tone (see below). Further stiffness can occur passively (e.g., due to rigor mortis; see Kobayashi et al., 2004), or actively, in which case it is modulated primarily by AMCC (Borghuis et al., 2008).

In pedagogical contexts, stiffness often carries a negative connotation - but this appears to be because the intended meaning of “stiffness” in these cases actually is “any stiffness in excess of what is required” (see below).

Clear scientific definition
Stein05_32
Steinhausen achieves a fairly clear, scientific usage of “stiffening” in equating it to an “action in the muscles” which “engages every muscle in turn” - necessarily implying the presence of AMCC, which is a key contributor to joint stiffness. However, “in turn” incorrectly mandates a sequential activation of muscles, when AMCC (and the associated stiffness) can be either sequential or simultaneous.

Matt08_06
Matthay states that “all stiffness…is produced solely by FAILING TO LEAVE INACTIVE the raising or ‘up-pulling ’muscles” - a largely accurate if exaggerated definition. Oddly, Matthay equates Anton Rubinstein’s “hand of iron” as not stiff and without AMCC, - yet “iron” suggests stiffness and rigidity, which are achieved via AMCC.

Matt08_11
Matthay is correct, though he exaggerates, in equating “stiffness” with “non-elimination of the contrary exertions”, given AMCC increases stiffness.

Matt14_01, Matt14_02, Matt14_05, Matt14_11, Matt14_21
Matthay correctly observes that AMCC ("opposite exertion…with the required one") increases "stiffness".

Ort25_02
Ortmann equates "stiffness" to "rigidity", which parallels scientific usage.

Matt32_01, Matt32_11, Matt32_12
Matthay correctly equates "Stiffness" with AMCC: "opposite exertions…along with the required ones…antagonistic exertions".

Matt32_03, Matt32_06, Matt32_07
The usage of "stiffness" can safely be assumed to coincide with Matthay's earlier clear, scientific usage (see Matt32_01).

Matt32_13
Matthay uses a clear, scientific definition of "stiffness" by equating it to "rigidity".

Field34_07
Fielden correctly equates "a form of stiffness" with "muscular restraint of the non-operating fingers", which implies (at minimum) AMCC at the wrist.

Field34_17
Fielden correctly equates alternating, reciprocal contractions of agonist and antagonist with "avoiding stiff…movement", implying that stiffness involves AMCC.

Sch36_02
Schultz equates a "stiff…elbow" with "contract[ing] the biceps and triceps muscles simultaneously", implying a scientific usage of stiffness as being caused by AMCC.

Sch36_08, Sch36_09, Sch36_11, etc.
The excerpts can safely be assumed to continue Schultz's clear scientific usage of stiffness. Any exceptions are documented here.

Sch36_34
The excerpt is only notable in that it begins to contradict Schultz's earlier statements against AMCC, either in the joint of movement or in general (e.g., Sch36_14, Sch36_29), without clear rationale.

Cov48_01
Coviello correctly identifies Matthay's meaning of "stiffness" by equating it with AMCC (see e.g. Matt08_11)

Bow61_01, Bow61_03
Bowen parallels scientific usage by observing that "stiffness is caused by retaining tension in the opposite set of muscles".

Koch67_08
Kochevitsky parallels scientific usage by equating "simultaneous contraction [of antagonists]" with "stiffness of the concerned part".

Lhév72_01

The excerpt indirectly defines “stiff” except by contrasting it with “flexible” - which parallels scientific usage.

Lhév72_02 Lhév72_03
The excerpts’ use of “stiffening” can probably be assumed to parallel earlier scientific usage (Lhév72_01). However, this usage surely precludes the claim that “[Anton] Rubinstein’s wrists were always free from stiffness”, given that there is apparently no reputable documentation of any pianist ever playing for extended periods with wrists entirely “free from stiffness”.

Ger07_04
Liszt implies a scientific usage of “stiff” by equating it to “rigid”, the latter which he also uses in parallel with scientific definition.

Fras11_23
Fraser implies a scientific usage of “stiff” by equating it to “rigidity”, the latter which he also uses scientifically.

Fras11_24, Fras11_25
The excerpt appears to continue Fraser’s scientific use of “stiffened”.

Clear unscientific definition
Matt08_07
Matthay claims that any exertion of muscles “opposite in function” results in “extremely stiff and restrained” movement, incorrectly equating all AMCC with extreme stiffness (when AMCC produces varying levels of stiffness).

Ort29_31
Here Ortmann departs from his earlier scientific usage, seemingly by an accidental terminological slip, by equating “sustained contraction” with “useless stiffness”; this incorrectly implies that any contraction (not just AMCC) constitutes “stiffness”.

Chi46_44
Ching identifies the common pedagogical definition of “stiff playing” to be an “excess of” AMCC (here “tension”).

Kent76_03
Kentner implies an unscientific usage of “stiffness” as meaning ‘muscular spasm’, describing it as when “the wrong set of muscles is involuntarily stimulated to sympathetic action by its counterpart”.

Bern81_07
Bernstein adopts an unscientific usage of “stiffness” to mean “exaggerated contraction of your muscles over which you have no control”. While stiffness can be involuntary in certain cases (e.g., involuntary, static AMCC resulting from music performance anxiety; see Yoshie et al., 2009), much “stiffness” is generated voluntarily. Essentially, the quality of “stiffness” is determined by physical properties, not volitional ones. A slight change in wording could have headed off this flawed implication: e.g., “an exaggerated contraction of your muscles over which you [sometimes] have no control”.

Sán81_03

Sándor implies a nearly scientific usage of “stiffness” by associating it with “simultaneous and extended activation of an antagonistic set of muscles”. Specifically ‘extended’ duration of AMCC, however, is not required to achieve stiffness, in strict scientific usage.

Mark04_04
Now Mark associates “stiff” with “tense”, the latter which he previously defined as in a state of “excessive muscular work” (Mark04_01).

Mark04_22
Here Mark associates “stiff” with “fixed”, the latter which uses in a clear, scientific sense - implying a clear unscientific meaning of “stiff”, because stiffness is only indirectly related to positional fixation (e.g., motion may still occur at a joint that is stiffened).

Unclear definition
Bach87_01
Because Bach (C.P.E.) does not define “stiffness”, we are unable to assess his claim that “[s]tiffness hampers all movement”.

Stein05_12
Steinhausen does not define “stiff”, so it cannot be assessed whether stiffness is a “rather generally widespread error”.

Gab13_01
The “stiffest imaginable kind of a touch” described here is not defined, except as a result of a “still, even rigid condition” - which leaves room for multiple meanings of “stiffest”.

Gab13_03
The “exaggerated mechanical stiffness” here lacks a clear definition.

Hof20_02, Hof20_03
Hofmann does not define “stiff”, despite advising that hands should be “still, but not stiff” during scales and arpeggios. This seemingly refers to a refined use of dynamic AMCC for stability, but this remains uncertain. Similarly, it is difficult to interpret his instruction not to “stiffen the wrist unconsciously” because he does not define “stiffen”.

Cort28_03
Cortot does not define “stiffiness[sic]”, prohibiting firm judgment of his claim of “disastrous stiffiness[sic]”. Moreover, no common usage of stiffness would validate the false claim that “the naturally curved position of [t]he index-finger on the key” will prevent “stiffiness[sic]”.

Field34_24
Here Fielden implies an unclear usage of “stiffness”, claiming that it “arises from too much contraction” - when previously he identified it correctly as equivalent to AMCC, here he seems to mean excess AMCC, but this is not entirely certain.

Field34_36
Here Fielden implies a further, unclear usage of “stiffness”, equating it to “continuous fixation of the arm” - which is itself unclear because Fielden does not use “fixation” clearly here.

Bac63_01

It is not clear which of two meanings of “stiffness” Bacon intends: either a scientific usage of “stiffness” as associated with AMCC, or a particular state of intense AMCC - which goes beyond scientific usage.

Gat65_28
Gat does not define “stiffly” except by contrasting it to “elastically”, which is not used clearly here either.

Gies72_03
The excerpt does not define “stiffness” except by contrasting it to “slight…tension”, but “tension” itself remains undefined.

Neuh73_01, Neuh73_02, Neuh73_04, Neuh73_07
Neuhaus does not define “stiffness”. He equates it with “tenseness”, which also remains undefined. Neuhaus also contrasts “stiffening” with “no contraction” - which leaves room for more than one meaning of “stiffening”.

Tay79_05
Taylor does not define “stiffness” but does imply rejection of the common pedagogical definition of stiffness (see e.g. Chi46_44) by stating “the origins of stiffness are not to be found in any deficiencies in the working of the muscles”, while an excessive and static form of AMCC (the common pedagogical usage above) could indeed be described as a deficiency in the working of the muscles.

Har80_03, Har80_04
It is not clear whether Hargrave defines “stiffness” as the “fetters of immovability” or as the “immovability” itself.

Har80_20
Hargrave contrasts “firm muscles” and “stiff [muscles]” but does not define either.

Last80_02
Last does not define “stiffness” here.

Bern81_10, Bern81_13
Bernstein does not define “stiffness” here.

Arr82_02
Arrau does not define “stiffness”, but contrasts it with “play[ing] in a relaxed way” - “relaxed” also being unclearly defined.

Ohl82_01
Ohlson does not define “stiff”, other than by contrasting it with “relaxation”.

Schi82_04
Schick does not define “stiff”.

Wat83_01
Waterman relates “stiff” with “tense”, suggesting a scientific usage, but defines neither.

Eig86_01, Eig86_02, Eig86_03, Eig86_04

The excerpts do not define “stiffness” except by associating it with “convulsive or cramped movement”, and contrasting it with “suppleness”, which is also not clearly defined.

Fink92_19, Fink92_23, Fink92_24
Fink does not define “stiffen” clearly.

Gri01_01, Gri01_18
Grindea does not define “stiff”.

Gri01_02
Here Grindea defines “stiffness” as “excessive TENSION”, but she does not define the latter.

Mark04_03, Mark04_15
Mark associates “stiff” and “fixed”, defining neither.

Ger07_08
Mason does not define “stiffness” except by associating it with “hardness” or “rigidity”, which he also does not define. He contrasts it with “stability, strength, repose”, but this does not make a definition clear.

Ger07_15
Debussy’s definition of “stiffness” is not provided here.

Vás07_01
Vásáry does not define “stiffness” here, contrasting it with “tension” and “relaxation”, which also remain undefined.

Fras11_09, Fras11_17
Fraser does not define “stiff”, though implying a nonscientific usage by suggesting that it contrasts with AMCC, the latter capable of “transmitt[ing]…great power”.

Fras11_41
After using “stiff” in a scientific manner (see Fras11_24 and Fras11_25), Fraser now reverts to an unclear, unscientific use by contrasting “stiff” with a “stable transfer of weight” - implying that “stiff” does not involve AMCC, which is required for stable transfer of forces across joints.

Fras11_46, Fras11_49, Fras11_50, Fras11_51, Fras11_53, Fras11_70, Fras11_75, Fras11_76, Fras11_87, Fras11_95, Fras11_104
Given Fraser’s inconsistent usage of “stiff”, we cannot conclusively determine his meaning here.

Dea17_01
The authors do not define “stiffness”, conflating it with “rigidity”, which is also undefined. A further association with “fixation” (also undefined) is not enlightening.

Kou20_01, Kou20_04
Koumis does not define “stiffness”.

Contraction

In biomechanics, “contraction” typically refers to the act of “shorten[ing] and generating a pulling force” (Gordon et al., 2022, p. 147). Muscle contraction therefore is defined as a muscle’s process of activating its fibers to (typically) exert pulling forces on bones via tendinous interconnections; however, ‘muscle action’ might be a more accurately inclusive descriptor of the phenomenon typically referred to as contraction, because not all muscle activation implies shortening - e.g., in the case of eccentric activation (Hazari et al., 2021). Nevertheless, because “muscle contraction” is a traditional, common term in the biomechanics literature, this article maintains its usage (while acknowledging its limitations, as above) - because the article focuses primarily on AMCC, a subtype of muscle contraction (or muscle action).

It is worth noting that “contraction”, in movement contexts, can also reasonably mean “the process of becoming smaller” (OED) - which implies certain situations of definitional uncertainty that usually go unclarified: for example, Cal03 contrasts “contract” with “expand”, implying a valid alternative usage (e.g., the muscles in the palm contracting (typical meaning) to abduct the fingers, resulting in an expansion of the hand’s reach; and conversely, the same muscles in the palm relaxing to return the fingers to a state of relative adduction, resulting in a contraction (alternative meaning) of the hand’s reach).

Clear scientific definition
Stein05_34
See Stein05_34 elsewhere.

Field34_10
Fielden achieves a clear scientific usage in identifying that “limbs can move of their own volition only by means of contraction”.

Schm35_10
The excerpt can safely be assumed to continue Schmitz’s clear, scientific usage of “contraction”.

Sch36_03
Schultz provides a detailed and scientific description of muscle contraction “caused by the individual fibers contracting”.

Schm35_09, Sch36_05, Koch67_01, Bern81_04, Sán81_06, Wins98_02, Wins98_05, Tub00_01, Tub00_03, Ger07_09
The excerpts imply the scientific usage of “contraction” by contrasting it with “relaxation”.

Sch36_18, etc.
The excerpts can safely be assumed to continue Schultz’s clear scientific usage of “contract”. Any exceptions are documented accordingly.

Ger07_49
Gerig uses “contract” in contrast with “relax”, paralleling scientific usage.

Fras11_22
Here Fraser implies a scientific meaning of “contraction” by equating “co-contraction” with “dual muscular pull”, or “when two sets of opposing muscles operate simultaneously”.

Fras11_26

Fraser uses “contraction” scientifically here by equating it to “tension”, which he is here using scientifically.

Fras11_84
Fraser uses “tension” scientifically after a long hiatus by describing contraction “from a muscle”, contrasted to being left in a “naturally soft state”.

Clear unscientific definition
N/A

Unclear definition
Cal03_15
While “contract or relax” seems to imply a scientific usage of both terms, Caland contrasts “contract” with “expand” frequently throughout the text and provides no other definitions; therefore, we cannot make firm conclusions about Caland’s use of “contract” here.

Field34_08
While the excerpt does not directly relate to AMCC, it seems to reveal some general confusion relating to muscle contraction on Fielden’s part: a “nervous impulse…kind of contraction not unlike muscular contraction” is plainly just ordinary muscular contraction.

Gies72_02
The excerpt does not define “contraction”.

Neuh73_04
Neuhaus equates “no contraction” with “completely relaxed” - which would seem to suggest a clear scientific usage of both, except that he advises the latter must occur during “playing”, precluding our clear understanding of either term’s intended meaning here.

Sán81_05
Sándor does not define “contract” - and suggests that “joints…must contract”, which implies at minimum an unscientific usage.

Tay81_02
Taylor equates “fixation” to “contraction”, defining neither.

Ger07_05
Liszt does not define “contraction”. His recommendation of playing “without the slightest contraction” precludes scientific usage.

Fras11_10, Fras11_11, Fras11_12, Fras11_14, Fras11_15, Fras11_21
Fraser does not define “contraction”, implying at minimum an unscientific definition by contrasting “habitual contraction” with “activation”.

Fras11_37, Fras11_60, Fras11_64, Fras11_102
Because of Fraser’s inconsistent use of “contraction”, and lack of further clarification here, it is not possible to precisely determine his meaning. Fraser also suggests without evidence that excess contraction results in “stifling the instrument and cramping its vibration” - but this is more likely to be a multisensory perceptual effect arising from the excess contraction, rather than actual changes in acoustic vibration (which should technically be affected, but entirely unnoticeably, by such contraction occurring at the keyboard or in the air).

Rob14_01
Beethoven's meaning of "contracted" is not specified here. It could plausibly mean either a muscular contraction, or a positional, postural contraction, in the sense of contraction and expansion.

Suppleness
The scientific literature lacks a standard definition of "suppleness", with researchers adopting varying usages: some equate "suppleness" with "flexibility", i.e., total possible range of motion in a joint (e.g. Al Dhuhaibwi, 2018, p. 10), while others define it as "the possibility of performing movements with maximum amplitude and ease" (Florina, 2022, p. 145). Suppleness has also been related to "elasticity" by some authors. Given varied scientific usage, it is worthwhile to also consider dictionary definitions of "suppleness": for example, the OED defines "supple" as "bending and moving easily and gracefully; flexible; not stiff or hard; easily manipulated", a multifaceted definition that appears to cover more than one of the above scientific usages.

Given that "suppleness" has been used as a descriptor alongside "flexibility" by pedagogues for centuries and across multiple languages, it reasonable to assume that "suppleness" has some distinct meaning beyond "flexibility". This suggests that "flexibility" on its own is an insufficient definition of "suppleness"- which is corroborated by the OED's multifaceted definition that includes, but is not limited to, "flexible". Clearly, suppleness in the context of human movement demands a certain adaptivity, pliability, or reactivity to applied forces: for example, the teeth cannot be considered especially supple parts of the body, because they significantly resist attempt at deformation until suddenly and irreparably giving way - e.g., by fracturing into pieces when being extracted due to "overzealous extraction technique" (Woodward, 2006, p. 126). This example seems to illustrate an inverse relationship between suppleness and inelasticity (as inelasticity is one means of explaining the above behavior of human teeth), and therefore a positive association between suppleness and elasticity - which does have a standard, scientific biomechanical definition (see above).

At this point, it is helpful to return to the question of whether "suppleness" is equivalent to "flexibility" - as human teeth are also inflexible, in addition to being not supple, and inelastic. Here, it is necessary to consider further premises - for example, what would constitute something "flexible" and yet "not supple"? Turning our attention temporarily away from the human body, we can consider the case of a wilting plant (e.g., a sunflower in ill health). The stem of such a plant would clearly be, at minimum, somewhat flexible (Rupprecht et al., 2015) - as the plant is wilting (before having completely desiccated, at which point a brittle inflexibility would take over). However, the stem would also be limp, due to the plant's ill health; this implies that, if one were to gently deform the stem from its natural shape, it would not readily spring back to its original form, but would instead remain at some stage between its most deformed position and its original state - therefore having higher plasticity and lesser elasticity. This example illustrates that "flexible" entities are not necessarily "elastic" entities (Zhang et al., 2017) - and therefore supports the notion that "suppleness" implies not only "flexibility" but also "elasticity".

It is necessary to consider one further question here: is suppleness therefore simply synonymous with elasticity, given that elastic materials themselves must be flexible? As a final example, consider a rubber cylinder such as those commonly used in physiotherapy

(e.g., the THERABAND® FlexBar®, which is made entirely from natural rubber[1]). Rubber is hyperelastic (Beda, 2007), springing back promptly to its original shape after nearly any deformation - but would we consider it supple? I propose the answer is “no, rubber is not supple” (despite occasional descriptions to the opposite effect, e.g., in Rajesh et al., 2018) - because the elasticity of rubber behaves forcefully and suddenly. If I bend a rubber cylinder into a U-shape, and release it adjacent to and in the direction of a wall, the cylinder will (apart from considerations of bending stiffness) snap suddenly back to its cylindrical shape and impact the wall forcibly. Why is this explosive elasticity not compatible with suppleness? Because, as suggested by the OED, “supple” also involves considerations of “ease” and “grace” - which are qualitative variables, not easily defined in mechanical terms, but clearly incompatible with sudden forcefulness.

We can now synthesize a loose standard definition of the term, following our prolonged exploration: “suppleness” is “a state of elasticity and flexibility that is characterized by ease and grace”. In biomechanical terms, this definition has a clear connection to the focal concept of this article: AMCC, and more specifically, near-optimal, proportionate, dynamic AMCC. This form of AMCC is what controls elasticity, which also implies a state that is neither limp (plastic rather than elastic), nor statically stiff (inflexible). It is therefore reasonable to conclude that “suppleness” in human movement is achieved at least in part by dynamic, appropriate AMCC.

Clear standard usage
Field34_24
Fielden asserts that “true suppleness lies in securing the full contraction at the right moment…the muscles are not in relaxation at all”. This indirectly implies a standard meaning of “suppleness” as involving properly timed and proportioned AMCC.

Eig86_01, Eig86_02, Eig86_04
Taken together, these excerpts suggest a standard usage of “suppleness” by Chopin - connected both to“eas[e]” and “flex[ibility]”. The contrast of “supple” with “stiff” (the latter which has an unclear, unscientific meaning here; a scientific usage of “stiffness” would instead muddle the meaning of “suppleness”) provides neither clarity nor confusion. Finally, the “supple” hand described as “keeping always a living, active link from each finger to the hand” is suggestive of dynamic AMCC - which itself is an implication of the standard usage of supple (see above).

Clear nonstandard usage
N/A

Unclear usage
Cort28_01
Cortot’s “thoroughly supple mechanism” is to be achieved by “effort…followed by complete muscular relaxation”, but lacks further definition.

Cort28_05
Cortot does not define “supple”, so it cannot be determined whether his “muscular efforts of a contradictory nature” could occur during a “supple and easy gesture”. Furthermore, while “muscular efforts of a contradictory nature” might seem to imply AMCC, the context (“increas[ing] the powers of…the third, fourth and fifth fingers” while simultaneously “on the

[1] https://www.theraband.com/products/flexbar (accessed 15 August 2025).

contrary…[lightening] the action of the thumb" implies a meaning that does not necessarily involve AMCC.

Field34_06
Fielden does not define "supple" except by relating it to "loose" here.

Tay79_05
Taylor defines suppleness as "a purely negative attribute…freedom from stiffness", but does not define "stiffness" clearly. Additionally, Taylor's claim that "[t]o try to create suppleness in the muscles is to attempt to create a possibility which already exists" seems to fall apart under closer inquiry, given Taylor's own definition of suppleness: as suppleness according to Taylor means "freedom from stiffness", then suppleness itself is not a "possibility" but a state, muscles and entities being the entities that possess the "possibility" to be supple. In short, a state of being is not the same as the possibility of entering that state - another clear example of this being sleep.

Tay81_01
Taylor does not define "suppleness" except by relating it to "utmost freedom" and contrasting it to "muscular relaxation", leaving room for multiple interpretations.

Dar82_02
Darré equates "suppleness" with being "relaxed", but does not define either.

Sode06_02
Thalberg associates "supple" and "relaxed", in contrast to "tension" - but defines none of these.

Ger07_03
Saint-Saëns does not define "suppleness" here.

Perl07_01
Perlemuter does not define "supple" - contrasting it with "tension", which also is undefined.

Fras11_09, Fras11_78, Fras11_83
Fraser does not clearly define "supple" here.

Vibrato
In scientific usage, "vibrato" typically refers to the rate and extent of pitch modulation in tones produced by pitch-modulatable instruments (Anand, 2012) - e.g., the human voice, the violin, or the flute. The piano is not pitch-modulatable in this sense (typically requiring special equipment and intervention, preferably by a trained technician, in order to change the pitch of the instrument, which is generally impractical during performance), and therefore this usage does not apply here. There is no common scientific usage of "vibrato" more generally in relation to muscle activity or biomechanics, especially outside of references to the muscles responsible for voice-production. The standard dictionary definitions of vibrato are also tied to pitch (e.g., "a rapid, slight variation in pitch in singing or playing some musical instruments, producing a stronger or richer tone" (OED) and therefore inadmissible here. Therefore, I proceed to derive the following contextual definition of "vibrato" from its etymological origin in Italian, "vibrare", which means "to vibrate". In turn, "vibrate" is commonly defined as "to move continuously and rapidly to and fro" (OED). Subsequently, "to and fro" is defined as "in a constant movement backwards and forwards or from side to

side” (OED); this quality of back-and-forth can be aptly represented by “oscillate”, which commonly means “move or swing back and forth in a regular rhythm” (OED).

We therefore arrive at a loose standard definition of “vibrato”, in contexts of muscle use, as “continuous and rapid oscillation”. This definition is suggestive of the presence of AMCC (Stanier, 1973; Winters & Stark, 1986; Tobalske & Biewener, 2008).

Clear standard definition
Sch36_18
Schultz defines “muscular vibrato” as “a rapid series of similar acts” of “movement” and “spring[ing] back”, in which one muscle “contracts…and then relaxes” while its antagonist “remains at a constant degree of contraction”. This clearly parallels the standard definition adopted here - a rapid oscillation of contractions and resulting movements, with continuous elements.

Sch36_20, etc.
The excerpts may safely be assumed to continue Schultz’s clear standard usage of “vibrato”. Any exceptions are documented here.

Sch36_21
Schultz provides a simple and useful instructive exercise demonstrating the basics of muscular vibrato. Readers are encouraged to attempt this exercise if comfortable, as it can provide embodied understanding of the concept of muscular vibrato, connecting the term to clear and probably familiar movements of the hand and arm. One point made by Schultz in this instruction might however be questionable: that there is “a point at which alternating contractions instead of the muscular vibrato are used”; more accurately, it seems that this point (when the extent of the wrist movements becomes especially large) allows for either continued AMCC (but the oscillation being too slow to be considered a true “vibrato”) or, as Schultz claims, “alternating contractions”.

Sch36_23
Schultz claims that the “little finger” cannot achieve a muscular vibrato, nor can the wrist in the movement of abduction and adduction. This seems largely correct - perhaps for reasons including insufficient mechanical leverage, insufficient elastic behavior of paired agonists and antagonists, or insufficient innervation density. Regardless, the only factor prohibiting these attempts from constituting a true “muscular vibrato” seems to be speed; i.e., the fifth finger and its corresponding musculature can move and contract in patterns that are equivalent to those occurring during a muscular vibrato, but too slowly to be considered “continuous and rapid oscillation” (emphasis added). This indirectly supports the definition of vibrato as including the quality of rapidity - argued for above.

Clear nonstandard definition
N/A

Unclear definition
Ort29_47
Ortmann identifies “vibrato touch” as “a very fast succession of staccato movements, more especially in the louder dynamic degrees”, but it is not clear what he means by “staccato movements”.

Ort29_48

Ortmann adds that the “vibrato coördination” implies “simultaneously contracted” muscles, including the “antagonistic” ones - this still does not constitute a clear definition, but the addition of AMCC brings him a step closer to a standard meaning.

Ort29_50
Ortmann observes incorrectly that the “vibrato touch” is “the one instance in which we can properly speak of an elastic condition of the muscles”. This still relates it to AMCC, given that AMCC enhances joint elasticity.

Field34_34
“one embracing impulse of nerve power” sounds fanciful and imaginary, muddling an otherwise clear nonstandard definition of “vibrato”.

Muscle tone / Muscle tonus / tonicity
Muscle tone is typically defined as “the ongoing tension within skeletal muscle that results from passive viscoelasticity and active tonic muscle contraction” (Cacciatore et al., 2024, p. 2). Importantly, both of these passive and active components are involuntary, “behaviorally distinct from and engag[ing] different brain pathways than voluntary control” (Cacciatore et al., 2024, p. 2). Here it is worth differentiating between these passive and active components of muscle tone, because only active muscle tone can be considered a form of AMCC (though involuntary and relatively weak), while passive muscle tone occurs even in wholly relaxed muscle (Enoka, 2008), yet can still impart some minute benefits similar to those that AMCC provides in greater degrees. For example, passive tone in the biceps and triceps brachii implies that some amount of force transfer, however miniscule, will occur across the elbow joint even in the absence of AMCC.

Matt14_11
Here Matthay states that a minor amount of AMCC is a necessary evil via “[t]onicity” (see Enoka, 2008, p. 309 for an alternative view), but that even this should be minimized by “forcing ourselves”.

Ort29_06, Ort29_14
The excerpts suggest that some amount of AMCC exists constantly and in every joint, apparently via muscle tone; see Enoka (2008, p. 309) for an alternative theory. In any case, the question arises: how much AMCC is required (in a given context) for its benefits to appear? The answer appears to be: ‘more than the minimal AMCC that could be present in the form of muscle tonicity’; otherwise, two corollaries are implied that both disagree with our prior model regarding AMCC’s variability and trainability: a) no physically healthy person would be missing the benefits of AMCC, and b), AMCC is not trainable in a beneficial sense.

Ort29_12
The excerpt distinguishes “changes in muscular tone” due to “emotional excitement” versus changes due to fatigue, hypothesizing that the former is “a real muscular contraction [and] a reflex resulting in a heightened efficiency to respond to any sudden stimulus”, and therefore not a true change in muscle tone. The hypothesis is perhaps simplistic and antiquated, and regardless is not of particular relevance here.

Schm35_12
Schmitz claims without evidence that we can “use the nerves to prevent contraction of antagonistic muscles, by causing in these muscles a diminution of muscular tone to less than the normally relaxed state”, supposedly resulting in “freedom of motion and economy

of energy". Muscle tone is not considered to be under conscious control (Ganguly et al., 2021).

Sch36_05, Sch36_07
Schultz identifies muscle tone as "essential…to the very machinery of movement".

Sch36_14
Schultz claims that "normal muscle-tone is adequate for the control of most pianistic movements" within joints that are actively used as sites of limb movement (e.g., the elbow during forearm flexion), cautioning "in a general way" against "movements in joints which are strongly fixed above a normal muscle-tone". Beyond the question of what "normal muscle-tone" entails, this recommendation seems incorrect. For example, during playing loud, rapid octaves, the sternoclavicular joint should likely be both "strongly fixed above a normal muscle-tone" (e.g., to absorb and dampen perturbations transferred from forceful key impacts through the distal-to-proximal kinetic chain) and a site of movement of the entire arm (e.g., if playing an ascending octaves scale with the right arm, continual adjustment of the scapula in the altitudinal plane - which occurs in the sternoclavicular joint via scapular elevation and depression - can help the arm to remain at the proper height to impact the keyboard whilst humeral abduction and likely additional torso movement are both functioning to bring the arm to each subsequent octave towards the upper register of the keyboard).

Gat65_04, Gat65_18, Gat65_20
Gat discusses some effects of the "natural muscle tonus". He claims that muscle tone is maintained at a higher level "the more developed and trained the muscles", which is often true (though not always; see e.g. Cacciatore et al., 2011).

Fras11_29, Fras11_68, Fras11_69, Fras11_86, Fras11_96
Fraser cautions that "bones and flesh…must not be inhibited by an overly tense muscle tonus", recommending instead to "maintain optimum balance between relaxation and activity" - but this incorrectly implies that muscle tone is under conscious control (Cacciatore et al., 2024). Similarly, Fraser claims that "healthy muscle tonus" is equivalent to "a continual and quite strong sense of contraction in the upper arm while playing", which is voluntary and should be exercised "at a certain stage in the development of one's technique". Fraser refers repeatedly to "muscle tonus" in a similarly flawed manner throughout large portions of the work; most mentions have been omitted here for brevity.

Kou20_07
Koumis asserts that "muscle tone may immediately reduce to the bare minimum", incorrectly implying that muscle tone is under conscious control.

Resilience
In scientific contexts, resilience typically relates to the maintenance of mental health via positive adaptation to adverse experiences (Herrman et al., 2011). The term "resilience" does not have a common definition in biomechanical usage. Therefore, we may refer to a standard dictionary definition of "resilience": "the capacity to withstand or to recover quickly from difficulties; toughness; the ability of a substance or object to spring back into shape; elasticity" (OED). In relation to biomechanics and the human musculoskeletal system, "to withstand" can imply the ability of a joint to withstand forces applied to it without displacement of the corresponding limb segment, while "to recover quickly" can imply the ability of a joint to quickly or even immediately regain the original position of its corresponding limb segment after a displacement has occurred - which is synonymous with joint elasticity, control of which is largely achieved by AMCC. To "spring back into

shape” can be interpreted in the same manner, and the OED’s final definition of “resilience” as “elasticity” simply reinforces the premise that “resilience” refers to a state of elasticity. Therefore, we may adopt a loose standard definition of “resilience” in a biomechanical context by slightly narrowing the focus of the OED’s definition: “resilience” here means “the capacity to withstand or recover elastically”. This definition in turn implies that “resilience” and “elasticity” can be treated synonymously - and noteworthily, controlling either implies the presence of AMCC.

Clear scientific definition
Field34_24, Field34_28
Fielden connects “resilience” with “true suppleness”, which he implies is equivalent to optimal, dynamic AMCC. By the transitive property, Fielden therefore connects “resilience” and optimal, dynamic AMCC - further corroborating this definition by observing that “resilience” requires “maintenance of…fluidity…without in reality reaching its vanishing point, relaxation”, which suggests dynamic activity between the extremes of static rigidity and total relaxation.

Sher96_03
Sherman suggests that a “completely resilient…fingertip” can “permit passage, both forward and back, of the stream of weight” and “onrush of energy” both from the arm and the key. This clearly implies a standard usage of “resilient” to mean capable of withstanding forces resulting from “weight” and “energy”.

Clear unscientific definition
N/A

Unclear definition
Field34_21
Fielden does not define “resilience” except by differentiating it from “stiffness” and connecting it to “supple”.

Field34_22
Fielden relates a “state of resiliency” in the muscles to being neither at “full relaxation” nor at “full rigidity”, implying a connection between AMCC and resiliency, but this is still somewhat unclear.

Field34_23
“Swift resiliency and recovery” remains unclearly defined.

Field34_27
Here Fielden regresses to an unclear, verbose usage of “resilience”, claiming it “lies…in eliminating (or inhibiting) all movements…except those that are determined upon as necessary to the performance of the action of allowing free swing to the movement once started”. This definition leaves room for multiple interpretations - with or without AMCC.

Har80_18
The excerpt introduces “resiliency” as a new word in contrast to “firmness”; unfortunately, no definition is offered, and the meanings of both remain unclear.

Mar82_01
Marcus does not define “resilience” except by stating that “relaxation…has resilience”.

Fink92_33
Fink does not define “resilience”.

Dub93_02
Dubal does not define “resilient”. Nevertheless,“ taut…steely” might suggest AMCC, while “the most fluid and resilient of sounds” seems to imply dynamism (rather than stasis).

Reciprocal inhibition
Reciprocal inhibition, likely discovered by Charles Sherrington (Sherrington, 1906), refers to a tendency during an agonist’s activation for its antagonists to be actively inhibited by the central nervous system (Day et al., 1984). If this tendency were omnipresent, unconscious, and entirely automatic, this would imply that AMCC can never occur. In reality, reciprocal inhibition is often overridden (whether entirely or in part), by the central nervous system (Takei & Seki, 2010), for example “when coactivation of muscles on both sides of a joint is needed to push or move in a specific direction” (Knudson, 2007, p. 100), allowing for the coexistence of both reciprocal inhibition and AMCC.

Sch36_05
Schultz’s claim that “[w]ith every neural impulse to contract a muscle goes an impulse to relax the tone of its antagonist” is an oversimplified description of reciprocal inhibition, which is not omnipresent. This oversimplification implies that reciprocal inhibition cannot be overridden- and therefore that agonist activation is always accompanied by at least partial relaxation of the antagonist, which is incorrect.

Sch36_13
Here Schultz implies that reciprocal inhibition is voluntary - which seems closer to the truth, and contradictory with Sch36_05 (see above).

Implicit endorsements of AMCC
Via stability
Cal03_01
Caland’s description of finger independence and stability suggests the presence of AMCC, which aids accurate, individualized finger movements.

Hof20_04
The excerpt implies AMCC by demanding finger movement simultaneously with a still “hand” and “arm” - requiring AMCC to achieve this stability against reactions from the finger motions.

Gat65_06, Gat65_09
Gat circles around AMCC terminologically by discussing “increas[ing] the elastic resistance of the support simultaneously with the increase in the force of the stroke” and “a gradual augmentation of muscle work” - all in order to “counterbalance[e]” the rebound of the key, which is only feasible via AMCC. Similarly, “counteract[ing]…rebound by a continuous elastic resistance” is only feasible via AMCC.

Bern81_14
Bernstein advises to “stabilize” the arms to achieve movement efficiency, strength, freedom, and “infinite control”. This stability requires AMCC, which is not clearly indicated.

Tay81_02, Tay81_03, Tay81_04

Taylor suggests a “brief moment of muscular tension…in order to control the reaction caused in overcoming the resistance of the key”, which requires AMCC - but the excerpt is terminologically vague. Similarly, Taylor advises “momentary firmness (or fixation)” to create “a strong enough base…to withstand and absorb the strong reaction or recoil arising from the energy expended in forte-playing”, which also requires AMCC.

New84_02, New84_03, New84_05
Newman advises an “essential stationary base”, protecting “speed and control”. This base is only achievable by AMCC. Similarly, without this “firm support or base”, the effect is akin to “weed[ing] with a rubber-handled hoe”. However, the metaphor of the “rubber-handled hoe” seems inaccurate; Newman is discussing the necessity of a “firm support or base”, but the metaphor suggests the necessity of a firm bridge across joints for force transfer, which is a separate function of AMCC.

Fink92_19, Fink92_20, Fink92_22, Fink92_30
Fink implies AMCC by recommending fingers “stiffen outward, adding to…stabilization support”; this requires AMCC. Similarly, having the body ‘firmly grounded”, to act as an “exceptionally firm base”, must also be accomplished via AMCC - as must “firm[ing] your fingers” and making the wrist “taut…prevent[ing] your hands from bouncing freely in the wrist”.

Fink92_32
Fink implies AMCC by advising that “the entire body must react to counterbalance…destabilizing forces”.

Tub00_02
The excerpt implies the usage of AMCC by advising that “joints…must be stabilized by other muscles”. However, the focus on “extrinsic tendons” is misleading by omission; the intrinsic tendons of the hand exhibit the same requirement of stability in order to “selectively mobilise a single [finger] joint”.

Tub00_04
The excerpt implies a robotic equivalent of AMCC for “efficient dynamic stabilization” in Honda’s “bipedal robot”.

Fras11_81
Fraser implies dynamic AMCC by demanding “you must be stable…without stopping the movement”, which requires dynamic AMCC.

Dor20_01
Liszt’s five-finger holding exercise implies the presence of AMCC (see e.g. Sch36_44, Sch36_45).

Via metaphor
Cal03_02
The metaphor of “muscles of iron” observed by Emil du Bois-Reymond (German physiologist, 1818-1896), who was alive and well-placed during the entire careers of both Franz Liszt and Anton Rubinstein (both to whom the quote refers), might suggest high levels of AMCC in eminent piano playing. Rubinstein reportedly advised Sergei Rachmaninoff to “press upon the keys until the blood oozes from the fingertips” in order to emulate his preeminently “sensuous piano tone”, perhaps corroborating this high level of AMCC and also its potential to cause injury (Schonberg, 1987, p. 271).

Sher96_04, Sher96_05
Sherman metaphorically and literally implies ubiquitous, dynamic AMCC by describing how "all his muscles and tendons begin to flex in rippling, circular sequence…a constant thrashing dance that revs up the juices…every ounce and limb contributing to the vortex of motion", and advising that "no part of the body is sequestered, inert, dead".

Via visual signs
Cal03_04
It seems likely that Caland's understanding of the "strict Deppean position" involves some AMCC: the "trembling" during unfamiliar and/or difficult movements, which is later minimized, could be postural instability being gradually controlled by AMCC over the course of motor learning.

Via multi-joint coordination and force transfer
Cal03_08, Cal03_09
Caland's connection of the "hand…impelled downward, not as the result of any individual movement of the hand itself, but solely as the result of an impulse originating in the energetic contraction of certain muscles of the back" implies AMCC to create the kinetic chain required for this multi-joint force transfer. The instruction to "think of the entire arm, from shoulder down, as whole" corroborates this multi-joint coordination that requires AMCC.

Stein05_20
The excerpt notes that "our organism…allows the muscles of the shoulder and of the whole arm to assist in a precise adapted way with the motion of even a finger joint", describing multijoint coordinations that are permitted only by AMCC.

Hof20_03
By recommending to "endeavour to transfer the display of force to the finger-tips", Hofmann implies AMCC for multi-joint force transfer.

Schm35_08
The excerpt observes that "muscles permit us to consolidate two or more [joints] together", which occurs via AMCC.

Dea17_09, Dea17_10
It is via AMCC that "the forearm can join with the upper arm, hand, and fingers to form the powerful whole arm lever" as a multi-joint system, and also via AMCC that "the mass of the arm [may] be transmitted directly to the key", or that "the forearm can simply transmit impulses from the upper arm to the fingers".

Via the stiffening and loosening of joints
Stein05_09
The excerpt observes that "muscles…either make the joint firm or relax it"; this is only possible via AMCC.

Fras11_08
Fraser implies AMCC by "activation of the hand's natural strength" to "fir[m] up its structure".

New additions to the model

Sensations, awareness, and appearances of muscle activity

Authors frequently commented on the sensations and appearances of muscle activity (including AMCC), one trend being that the presence of a particular muscular state in the pianist's body does not imply that the pianist is necessarily aware of the state. Similarly, it is a common (and scientifically sound) observation that two visually identical states can conceal two contrasting kinds of muscular activity (Mizrahi, 2021). Given that AMCC is trainable and has significant effects on piano performance, it stands to reason that an integrated model of AMCC includes consideration not only of how one can (and cannot) identify AMCC, but also how these varied means of identification can be valuable in the context of learning and assessing AMCC use - two activities that are indispensable to the article's overall aim of aiding pianists, and moreover implicit in any practicable model of a learnable activity.

Matt14_13, Matt14_15

Matthay recommends "noting the sensation" of contractions in order to omit AMCC. Similarly, he advises "we must eradicate all sensation of restraint" occurring via AMCC.

Stein05_35, Stein05_36

The "feeling of complete relaxation…in spite of the supporting effort of the finger muscles" seems to identify a sensation of relaxation combined with the reality of AMCC being present. Even more clearly, "[t]he subjective sensation…of…relaxation of all tension" occurs "in spite of the muscular activity actually taking place".

Ort29_10

The excerpt observes that rigidity is "not felt as rigidity" when "its degree is favourable for the proper execution of the movement", suggesting that AMCC can be somatically invisible when functionally integrated.

Ort29_11

Ortmann discusses "fatigue" experienced as "sensations of strain or rigidity" at the "joints", but seems to exaggerate the extent to which fatigue is experienced at joints rather than also within muscles themselves. Ortmann correctly identifies that this fatigue makes "judgments on extent, degree, and direction of movement more difficult".

Matt32_01

Matthay observes that "if two antagonistic exertions are precisely equal, then nothing happens visibly, but you can feel the tense struggle".

Sch36_31

While it is incorrect that this trunk stiffness is always "made instinctively", the thrust of the excerpt is that trunk AMCC can occur without the "awareness" of the pianist.

Chi46_12

Confusingly, the excerpt seems to contradict Ching's theory of no AMCC at the joints of movement (see Chi46_03, etc.), by suggesting that at a "joint of movement", "absence of sensations does not…necessarily indicate that no antagonistic tension is present". Regardless, the excerpt identifies that AMCC can occur alongside "absence of sensations".

Chi46_30

Ching asserts that sensitivity to AMCC (here "tension") is "one of the most important single factors in the acquisition of all technical skill".

Chi46_38, Chi46_51, Chi46_61
Ching recommends that successful coordination be judged by the “actual sensations produced”, such as “sensations of ease or difficulty, comfort or discomfort”.

Harr53_02
Harrison observes actions that “are not the pure relaxation” yet have a “sensation of freedom and ease”.

Harr53_03
Harrison notes that the “general appearance of relaxation” can be “as deceptive as the apparent relaxation of a cat walking along the top of a garden fence”, suggesting that “movements seem easy and nonchalant because they are, in fact, beautifully precise”.

Bow61_04
Bowen differentiates between AMCC at a joint (which he correctly relates to stiffness; see Bow61_01) and “a feeling of strain or stiffness”, implying a difference between biomechanical and sensory “stiffness”.

Gat65_04, Gat65_29
Gat observes that AMCC can occur while experiencing the “feeling of…being perfectly relaxed”.

Gat65_07
Gat discusses achieving a “sensation of absolute sureness”.

Kent76_05
While Kentner does not clearly define “stiff” and “relaxed”, the clear gist of the excerpt is his suggestion that two external appearances of movement may “look very much the same” despite reflecting different internal muscular states.

Bern81_03
Bernstein observes that one may confuse “comfort…as a state of total relaxation”, when in fact “controlled tension” is being exercised.

Bern81_04
While the excerpt is physiologically simplistic (e.g., which is the “lower leg muscle”; how does one “tighten a muscle” without implying movement and without the contraction of multiple muscles - for example, by pressing the leg into the floor, but this is not specified), here Bernstein mainly advises that it is important to “recognize the sensation resulting from contracted muscles”, which is “more easily said than done”.

Bern81_08
Bernstein advises that “being aware of muscular sensations enables you to generate the exact amount of tension needed for each musical feeling”, suggesting the musical and physical values of awareness of muscle sensation.

Kay03_02
The observation that “reports were commonly incoherent and contained little in common with what was revealed by the record”, though harsh, implies the difference in sensation and reality of muscle activity.

Mark04_04
Mark observes that “two movements of the hand may look outwardly similar” yet vary in underlying muscular activity.

Mark04_30
Mark asserts that “muscles may be tense, but we don’t notice because we’re not aware of them in the first place”.

Igum07_01
Igumnov denotes a general importance of “muscular sensations” as “something that has to be felt…when playing the piano”.

Fras11_21, Fras11_32
Fraser comments that when AMCC “functions normally, you will not experience it as such”. Similarly, “participation of all muscles may not be perceived as such”.

Fras11_38
Fraser recommends a process of “direct[ing] our attention to particular sensations associated with…movements”.

Fras11_89
Fraser observes that some muscles may be “chronically contracted”, and yet “we don’t feel the contraction”.

Fras11_98
Fraser gives an exercise to “instill the strange feeling of utterly free, seemingly contraction-less movement in your fingers” - clearly differentiating between contraction and perception thereof.

Wall13_01
Wallick correctly identifies Bernstein’s valuing of sensations in learning to play expressively (see e.g. Bern81_08).

Dea17_04
The authors imply that relaxed or contracting states can be visually identical: “even when there is no visible movement, muscles may still be contracting”.

Kou20_02
Koumis recommends to “notice the feeling of tension, then release”.

Ideomotor theory / ‘form follows function’
Ideomotor theory, coined by William James (1890), proposes that “humans generate voluntary actions by imagining the sensory consequence of those actions” (Shin et al., 2023, p. 1). While an ‘old ’theory by the standards of modern psychological science, recent research provides strong evidence for ideomotor theory - including in the pianistically relevant context of key-pressing (e.g. Wulf and Prinz, 2001; Shin et al., 2010; Shin et al., 2023). In seeking a practical model of AMCC, which itself is principally a ‘voluntary action’ with ‘sensory consequences’, it is necessary to consider ideomotor theory (by this particular label, or any suitable) - because in the practical context of piano performance, which primarily is used as a tool for musical expression, AMCC (like any voluntary action with sensory consequences) must be considered in part on the basis of these consequences - i.e., its musical, technical, and bodily effects. In other words, focusing on the states of AMCC

themselves - their presence, intensity, dynamic variability, (etc.), in each and every pair of muscles and at every joint, is by definition an insufficiently broad focus in the context of piano performance, because the latter's purpose is not the achievement of particular muscular states (nor even of particular movements), but of musical expression. This necessity of an ultimate musical aim may seem self-evident in the context of piano playing, but the blatant obviousness of this necessity is exactly what allows the risk of its importance being overlooked, by the assumption that it is an indefatigable and therefore forgettable necessity - for example, through the attractive but ultimately counterproductive efforts by pianists and pedagogues to find shortcuts to skilled piano playing by artificially refocusing their attention at length on bodily mechanics (necessitating a corresponding reduction in attentional capacity that can be directed not only to musical concept but also to musical results).

Agreement
Stein05_40
If Rupert's interpretation is correct, then Steinhausen supports ideomotor theory by judging that "the motion is determined by the musical necessity…primary emphasis on…the musical object".

Stein05_49
Rupert identifies a "psychic connection between motion and artistic thought", advising that "to locate and use the muscles…is not enough. The musical result must be unified with the motion used…The separation of the mechanics of technique from musical expression is wrong; they must be dependent on one another". This loosely supports ideomotor theory and its union of process and outcome.

Matt08_13
Matthay's demand that "no note should ever be sounded without a definite purpose as to the quality and quality of the sound, otherwise…the worst of all possible faults [occurs]!" accords with ideomotor theory.

Gab13_04
Gabrilowitsch recommends that the pianist should "think first and always of the kind of tone he is eliciting", rather than "the muscles and nerves", nor the "keys". This preference for musical outcomes over physical methods is consistent with ideomotor theory.

Sch36_01
Schultz describes that movements, rather than muscles, are represented in the central nervous system, according with ideomotor theory.

Sch36_39
Schultz advises that it is best to evaluate performance by dynamics, tempi, and articulation ("control of intensity, velocity, and above all, legato"), rather than by "physiological terms", in agreement with ideomotor theory.

Chi46_07
Ching cautions against "attempt[ing] to control voluntarily the processes of individual muscles", which he claims is "always a highly dangerous procedure…always interfer[ing] with the fine control of movements". Instead, Ching recommends focusing "in terms of the movements", agreeing with ideomotor theory.

Chi46_15

Here Ching goes a step further by claiming that voluntary control of individual muscles is entirely impossible - an exaggeration, but one that continues the same agreement with ideomotor theory as in Chi46_07.

Chi46_18
Ching extends his support of ideomotor theory by suggesting that “the whole question of tension should be associated in our minds with the question of tone”.

Chi46_20
Ching continues his support of ideomotor theory by advising “there should never be any conscious attention or direction given to any technical process under conditions of performance” (performance here referring to, e.g., a piano recital, rather than any act of piano playing).

Chi46_23
Ching continues to agree with ideomotor theory by advising to listen for “tonal results [that] are satisfactory” in order to “decide whether or not we need” AMCC.

Chi46_31
Ching parallels ideomotor theory by recommending the formation of “associations…between tones of different loudness and the particular degrees of tension which are necessary to produce them”. He identifies this process as “an essential part of the total psycho-physiological mechanism for controlling tone”; the term “psycho-physiological” is loosely synonymous with ‘ideomotor’.
Chi46_32
Ching recommends monitoring gradation of AMCC via “tonal results”.

Chi46_40
Ching’s point about “profound human emotions” being “quite contrary to” the “total absence” of AMCC mounts a psychological defense of AMCC “in its relation to the expression of our deepest emotions”, implying that emotional expression is primary, and bodily effort secondary.

Chi46_50, Chi46_61, Chi46_63, Chi46_64
Ching recommends to “listen carefully to the musical results which you obtain” due to varying AMCC (here “tension”) in order to judge and adjust the AMCC. Similarly, “making proper use of our ears”, “judg[ing] by the sound” to determine “whether our physiological conditions are correct”.

Chi46_62
Ching observes how novel sensations of AMCC can feel particularly unfamiliar and therefore appear incorrect or uncomfortable solely on the basis of their novelty.

Bon53_01, Bon53_04, Bon53_06, Bon53_07, Bon53_09, Bon53_10, Bon53_11
Bonpensiere’s theory of “Ideo-Kinetics” and “Physio-Kinetics” (and the gist of the work overall) aligns loosely with ideomotor theory, but take the suggestion of focus on outcome over physiology to the extreme. For example, Bonpensiere frequently makes extraordinary claims without basis, to the effect that “we can state a priori that a perfect physical predisposition to piano playing can be acquired Ideo-Kinetically before one has ever touched an instrument”. Bonpensiere takes excessive caution against “extended sensory guidance” by advising to “never think of your music in terms of execution…but in terms of interpretative rendering”.

Bac63_04
Bacon observes that “music is seldom loose-jointed…its tensions will unconsciously evoke physical tensions in the player”, similarly to Chi46_40.

Gat65_05
Gat exaggerates by claiming that control of AMCC should “never become conscious”, in preference of musical awareness.

Gat65_11, Gat65_12, Gat65_13, Gat65_14, Gat65_16, Gat65_17, Gat65_19, Gat65_27
Gat astutely identifies a flaw in the conclusion drawn by “many theoreticians” (e.g., Cal03_14, Matt14_07, Cort28_01, Ort29_52, Sch36_35, Chi46_49, Harr53_04) that the pianist should relax immediately upon reaching the “escapement level” of the key, which has the “apparent appeal of…saving muscle work”, but in reality, “will ruin not only our technique but…even our musical imagination”. The principal danger of such an approach (apart from its neglecting AMCC) is its preferencing of muscle dynamics over musical expression - in conflict with ideomotor theory. Instead, Gat proposes “there must be a close interrelation between musical imagination and physical motion…the variations of the movements should exactly follow the modifications of the musical concept”, because “to determine the correct action of the muscles, our only possible course is to start from the most intensive musical concept possible”. For example, “if we dare to imagine a crescendo in a chord…our movements will adjust themselves to this conception”, so that “the correct muscle work will become proportionately more and more differentiated with the increase in intensity of the musical concept”. However, it is worth remembering that there is no guarantee of this improvement in muscle work due to improved musical concept - the musical concept is not a guarantor but a prerequisite of the correct muscle work.

Gat65_31
Gat exaggerates somewhat by claiming that “technique in its entirety thus depends directly on the musical concept”.

Koch67_05
Kochevitsky writes firmly in favor of ideomotor theory by stating that the “musical idea…must always precede the motor reaction”. The work contains prolonged discussions of this theory (e.g., “auditory stimulus…anticipation of motor act…motor act resulting in actual sound…auditory perception and evaluation of the actual sound”; Kochevitsky, 1967, p. 30), which have been omitted here for brevity. Readers interested in Kochevitsky’s insightful analysis are directed to consult the work itself.

Neuh73_03
Neuhaus advises that “the greater the musical confidence, the less the technical insecurity”, implying a primacy of musical concept over physical act (though an exaggerated one, as exceptions can easily be imagined to his rule).

Mans94_01
Manshardt suggests the primacy of musical expression by declaring that “no amount of sensitive relaxation will ensure a beautiful result”.

Walk05_01
Liszt clearly implies the primacy of musical expression by asserting that “technique should create itself from spirit, not from mechanics”.

Alt06_01
The excerpt corroborates experts' preferencing of expressivity over mechanics by finding that "in emotionally intense playing even experts preferred expressive gestures over 'economical' use of forces".

Ger07_01
Gerig asserts the primacy of musical expression over mechanics, suggesting (perhaps naively) that "the music itself is the best teacher of both interpretation and technique".

Sher07_01
Sherman supports ideomotor theory by cautioning against "pure motion…unqualified by…musical criteria", which becomes a "circular thing".

Fras11_02, Fras11_16
Fraser suggests that the "ear must be the ultimate judge", as otherwise "the physical is not aligned with the aural", causing "even your most assiduous efforts [to] be for naught". Similarly, "correct positions [and] movements become the by-product of appropriate musical activity".

Fras11_25
Fraser identifies an "artistic symbiosis of form and function" through the use of AMCC to produce a "rich, singing cantabile".

Fras11_39
Fraser implies the primacy of musical expression by quoting Gekić that "You can't play Chopin if you're thinking about your ribs".

Fras11_108, Fras11_109
Fraser advises that "tone improves drastically when musical movement is reflected exactly in your physical movement", cautioning against "physical movement go[ing] contrary to the musical movement".

Disagreement
Matt14_07
Here Matthay insists that "all force employed to produce tone…must therefore cease the very moment that Sound-emission begins", implying a preference for mechanical efficiency between note onsets - even if the musical concept would prohibit such relaxation. This disagrees with ideomotor theory, but narrowly avoids self-contradiction with Matt08_13 because the latter can be interpreted as supporting ideomotor theory only during the moment of note onset.

Field34_32
Fielden suggests that "the conquest of any technical difficulty should be approached from the purely gymnastic standpoint", leaving no room for ideomotor organization via musical interpretation and desired sound.

Schm35_02
The excerpt falsely claims that "to perform completely and economically a muscular action it is necessary to understand clearly its mechanism". This implies that knowledge of the action itself, rather than its outcome, is mandatory - in conflict with ideomotor theory. One obvious counter-claim is "muscular action" in animals, who often can move "completely and economically" yet apparently do not "understand clearly" the actions' mechanisms.

Chi46_01
While not explicitly relevant to AMCC, opening statements and underpinning definitions provide a foundation for any discussion of AMCC to follow, so the excerpt is worth assessing here - this excerpt denying the importance of musical expressivity with its claim of “piano playing” as “a skill dependent solely on…postures…movements…muscles and joints”.

Chi56_06
The excerpt suggests using “tables of tensions” to analyse passages that are unsatisfactory - which might contradict Ching’s prior recommendations of analysis via musical results (e.g., Chi46_32, Chi46_50).

Chi56_06
The excerpt suggests using “tables of tensions” to analyse passages that are unsatisfactory - which might contradict Ching’s prior recommendations of analysis via musical results (e.g., Chi46_32, Chi46_50).

Fein07_01
Feinberg astutely suggests something similar, yet clearly distinct from ideomotor theory’s standard sequencing of expression and mechanics, by asserting that “melodious playing depends on efficacious movement, and expressivity depends on its plastic physical embodiment”.

Ger07_46
Gerig contradicts one of his own opening statements (Ger07_01) by claiming that AMCC “should always be kept at the lowest possible levels” - suggesting a primacy of inexpensive mechanical expenditure (itself a flawed goal) over musical expression.

Fras11_84
Fraser contradicts his earlier support of ideomotor theory (see e.g. Fras11_39) here by claiming that “stronger contraction[s]” should ideally be released “immediately after the contraction”, apparently for so-called energetic efficiency.

Dea17_02
The authors imply a primacy of mechanics over expression by advising that “the goal of efficient piano playing is…to active the right muscles…only up to the necessary level of intensity so that muscular effort is maximized and fatigue is avoided”.

Multisensory effects on piano playing
Multisensory effects on musical performance are well-documented (Ashkenazi, 2021); some of these effects are connected with AMCC: for example, varying AMCC used in between notes, before the first note of a piece, or after the final note of a piece can still have meaningfully varied implications for the pianist and their audience (if any) - yet without necessarily implying any variations of force applied to the piano keyboard.

Justified agreement
Ort29_57, Ort29_58
A clear acknowledgment of the multisensory, complex nature of piano timbre, such as “qualities…read into sound that cannot possibly exist there”, and “a rich source of kinesthetic and visual memories upon which [the pianist] constructs…imaged phrasing” - in contradiction with Ortmann’s prior rejections of multisensory effects (as early as Ort29_01 and as late as Ort29_56).

Gat65_13
Gat is clearly aware of multisensory effects on piano performance, as he observes that “if we dare to imagine a crescendo in a chord, if we make ourselves believe that the tones grow stronger after they have been sounded, our movements will adjust themselves to this conception and the tones will produce the illusion of becoming stronger”. While the word “illusion” carries perhaps too negative a connotation, the statement is otherwise entirely correct regarding multisensory perception of piano sound.

Con00_05
Conable indirectly implies multisensory effects on musical expression by suggesting that “quality of movement determines quality of sound”.

Fein07_01
Feinberg asserts multisensory effects on “singing quality in performance”, through the use of ‘tangible expressive movements of the hand” (which may occur after key-depression and therefore after most determinants of objective tone quality can already be predicted).

Gold07_03
Here Goldenweiser achieves a more satisfactory defense of multisensory expression by suggesting that “what I observe when I watch someone play should actually assist my aural appreciation and not interfere with it”, due to its “vital and essential” connection with “the psychological state of the performer”.

Ger07_10
Deppe implies multisensory musical expression with the “axiom, ‘a flat pose of the hand sounds flat”.

Ger07_40
Gerig now states Ortmann’s position on tone quality more accurately (see Ort29_54, Ort29_57, Ort29_58).

Rob14_04
Roberts correctly observes that awareness of non-aural sensations (e.g., “the key’s resistance”) can “give the pianist the impression of manipulating sound quality”.

Rob14_05
Roberts’ astute observation of Deppe’s implying that “tone quality…was in some way ‘flowing’” appears to corroborate the multisensory capability of continual control of perceived tone quality, even in decaying notes that have already been struck.

Justified disagreement
N/A

Unjustified agreement
Gold07_01
Goldenweiser observes that the “seemingly ‘dead’ instrument in fact reacts to every slight movement of our hands, arms and bodies”, such that the “visual impression made on the listener and the physical sensations of the performer, as well as the actual sound produced by the instrument” are each of “such importance”. In fact, human sense perception is what

reacts to “every slight movement” - not the piano itself, which in reality is only capable of objective, acoustic outputs.

Ger07_39
Gerig seems to misstate Ortmann’s studies of tone quality, implying that there were qualitative differences in objective, acoustic tone independent of dynamic (which Ortmann largely did not observe; see Ort29_54, Ort29_57, and Ort29_58).

Fras11_03
Fraser claims that “reducing the duration of your muscular impulses to effective lengths” will result in “richer tone” - indirectly implying a multisensory effect on a decaying piano tone, but strangely, one that behaves conversely to expectation: rather than maintaining muscular impulses to enrich a prolonged tone and imbue it with further connotations, Fraser somehow believes that “reducing” those muscular impulses would enrich the tone, which appears incorrect.

Unjustified disagreement
Matt14_07
Suggestions to relax muscular activity immediately upon the “moment that Sound-emission begins” indirectly imply disagreement with the multisensory nature of piano playing, because they deny all expressive capabilities that can occur due to non-aural sense data during the inevitable and largely predetermined decay of an individual piano tone.

Ort29_01
Given multisensory overlaps in perception of piano timbre, this statement, a foundational premise at the outset of Ortmann’s most ambitious work, is incorrect.

Ort29_23, Ort29_24, Ort29_31, Ort29_32, Ort29_52, Ort29_54
By expecting “the relaxation [of antagonists] to parallel the contraction…when movement has stopped”, Ortmann discounts the multisensory nature of piano playing, in which antagonist contraction may continue after movement ceases, due to expressive aims. Similarly, equating an “incoördinated” movement with any use of “antagonistic muscles” to “reduce the speed” of playing movements ignores the differences in quality of movement which can have multisensory effects on the perception of piano performance, e.g. via varied proportions of agonist and antagonist contraction. Claiming that “sustained contraction” is “useless stiffness…pianistically undesirable” also ignores multisensory effects, as does demanding that “contraction should cease not later than removal of the resistance”, “relax[ing] immediately after tone production”. It is also misleading to state that “however fanciful our conception of the artistic phases of piano touch may be, whatever poetic qualities we assign to the piano tone, the fact remains that percussion and intensity are the only determinants…prove[n] readily…by anyone taking the trouble to set up the necessary recording apparatus”. (See Ashkenazi, 2021 for a differentiation of piano tone as heard by the human ear versus as captured by a recording device).

Ort29_25
An oversimplification of the complex nature of piano timbre.

Ort29_56
It is only true that “this cannot carry over into the sound” if “sound” is taken objectively (i.e., not perceptively and multisensorily; the word ‘sound’ can carry both connotations: perceptively, as in “what did it sound like?”, and objectively, as in “undetected sounds”). In

terms of how we perceive such sounds, this “intensity of feeling” can “carry over into the sound”.

Sch36_12, Sch36_14
Schultz observes that AMCC “made unnecessarily constitute[s] a waste of energy”. However, this precludes optional AMCC, chosen for aesthetic expression via its multisensory effects - which cannot be called a “waste”, given that the essential purpose of piano technique is to perform musical expression.

Sch36_35
Schultz recommends the cessation of AMCC “at every possible rest-period the musical score provides”, implying (given his denial of multisensory effects) no usage of AMCC for multisensory expression.

Chi46_52
The excerpt recommends a strict association between tempo and AMCC, which ignores the possibility of varied AMCC for multisensory expression at any tempo.

Chi46_54, Chi46_55
Ching recommends that the playing unit with “the greatest inertia” is “the most efficient” due to greater inertia reducing the amount of AMCC for stability necessary, discounting the multisensory effects of different playing units (and different AMCC).

Gat65_11, Gat65_19
Gat states that “the pianist is unable to modify the tone once sounded” - which is only true in a strictly acoustic fashion, rather than the more relevant perceptual fashion. Even more problematically, he states that “the sensation of tone colour is not produced by the objective tone colours but jointly by the relative tone volume, the apportioning of the noise-effects and the agogic shaping”; the unfortunate word choice of “sensation” makes the statement strictly false and moreover contradictory with his earlier, more correct acknowledgment of “illusion[s]” of tone colour via musical “conception”, “imagin[ation]”, and the “movements” themselves.

Fein07_02
Feinberg claims that keeping the hands “forcibly pressed down…after the notes have been struck” is “an excessive waste of energy…[and] pointless”; this contradicts Fein07_01, which advised “tangible expressive movements of the hand” - which could plausibly include keeping the hands “forcibly pressed down” - and also wrongly denies multisensory effects on musical expression.

Fras11_79
Fraser claims that “ris[ing] off the piano bench for [a] most impressive forte” is “ridiculous…wasted energy…that has nothing to do with creating sound”, implying a clear denial of multisensory effects on piano performance.

Dea17_08, Dea17_11
The authors recommend that “muscle contraction…should cease once the resistance is removed…as soon as the point of escapement is reached”, to “build in quick releases…small moments of rest”. This implies a denial of the multisensory effects achieved by varied actions taking place after the “point of escapement is reached”.

Newton’s third law

Isaac Newton's third law of motion states that “to every action, there is always opposed an equal reaction”, or similarly that “the mutual actions of two bodies upon each other are always equal and directed to contrary parts” (Cornille, 1999, p. 166). While this law may be broken in some physical contexts, it appears largely true in the physical matters related to piano playing, and has been described as “the most important law in physics” (Cornille, 1999, p. 162).

At the piano, Newton’s third law explains the unavoidable reactive forces between finger and key, as well as the displacement of a limb segment resulting from its acting as a fulcrum to movements of its adjoining limb segment(s); both cases are broadly undesirable if left uncontrolled, while their control is best achieved by dynamic modulation of AMCC, indirectly connecting Newton's third law to AMCC.

Stein05_46
Rupert restates Newton's third law and identifies (but does not define) “fixation” as a solution to “counteract finger action”.

Ort29_05
A restatement of Newton’s third law.

Ort29_18
“Equal and opposite” force from key “impact” creating an “upward jerk at the wrist” clearly invokes Newton's third law.

Ort29_21
“Action and reaction are present also” refers to Newton’s third law.

Chi46_59
“Action and reaction are equal” refers to Newton's third law.

Sher96_02
“No action without reaction” refers to Newton's third law.

Dea17_07
The authors provide all three Newtonian laws of motion.

Musical effects of AMCC
Given that piano performance is principally a tool for musical expression, any model of AMCC in piano playing must thoroughly consider its potential for musical effects - whether positive, negative, or otherwise. Our prior review found scarce discussion of AMCC’s musical effects in scientific literature; pedagogues have had far more to say on the matter.

Justification and dis/agreement were judged here somewhat loosely, according to whether each claim of musical effect appears to be backed by our prior model of AMCC. For example, Field34_29 states that avoiding AMCC causes the pianist to “los[e] all instinct for power and dramatic intensity” - clearly an exaggeration, but one that nevertheless closely relates to the model’s finding of AMCC’s benefits for speed and power output the excerpt therefore was best categorized as a ‘justified agreement’ despite its hyperbole.

Justified agreement
Cal03_13

The excerpt relates AMCC with legato by associating “smooth and connected execution” with an elasticity that itself implies AMCC.

Matt08_03, Matt14_03
Matthay is incorrect in suggesting that AMCC necessarily results in inaccuracy of musical expression: “eliminating all contrary exertions…renders possible…accuracy in musical expression”. Similarly, “the real ‘secret ’of all good tone-production” is not merely “the complete possible Relaxation of all muscles that should be passive”.

Matt32_01, Matt32_13
Matthay incorrectly suggests that AMCC necessarily causes negative musical effects, such as the loss of “beauty of tone” - effects which the audience “will certainly hear…if they are musical”.

Field34_14
The excerpt suggests that AMCC can cause “crispness…of attack”, “crispness” being a qualitative musical descriptor.

Field34_24
Fielden suggests that optimal AMCC (here “resilience”) allows the pianist to avoid both “flabbiness” and “hard, thumping tone”, implying musical benefits of AMCC.

Field34_29
Fielden observes that “avoiding” AMCC (here “tension”) causes the pianist to “los[e] all instinct for power and dramatic intensity”.

Fielden34_30
Fielden asserts that AMCC (here “hold[ing] the forearm and hand in a state of contraction…controlled fixation” is the basis which “gives authority and definiteness to a performer’s interpretation”.

Field34_31
Fielden advises that AMCC (here “tension”) is required; otherwise, the pianist may experience “physical comfort, but it is anything but exciting to his audience”.

Sch36_38
Schultz notes that the “finest legati in conjunction with the subtlest control of intensity can only be achieved by” AMCC - this is in partly due to its beneficial effects on movement accuracy and precision.

Chi46_93
Ching identifies AMCC (here “tension”) as a necessary ingredient to achieve “the brightest, sharpest tonal effects” in “finger passages”.

Chi46_97
Ching discusses complex multijoint AMCC for achieving “a non-legato effect, and/or a bright, sharp or brilliant qualitative effect”.

Bow61_06
Bowen observes that excessive AMCC will “impede production of beautiful tone”.

Sán81_03

Sándor suggests that AMCC will “ultimately result in a poor sound”.

Mans94_02
Manshardt recommends an “antagonistic use of…muscles”, to “press and lift at the same time”, as a “necessary condition for tonally expressive playing”.

Bru97_12, Bru97_15
Bruser falsely claims that ‘“co-contraction ’creates a harsh tone and limits…expressiveness”, and one may achieve a “fuller, richer sound” by “relaxing…the muscular co-contraction”.

Ger07_43
Gerig claims that AMCC-based movements are “superior…in almost every way, when measured in musical terms”.

Fras11_23
Fraser suggests that AMCC is a “crucial tool in producing many types of forte legato, large blocks of orchestral sound or the type of percussive ostinato we associate with Prokofiev.”

Fras11_24
Fraser implies that AMCC can be required to “fulfil the…musical function”.

Fras11_25
Fraser suggests that AMCC may be required to “produce a rich, singing cantabile”, making use of “a balance of opposing qualities of force” in order to create the “artistic symbiosis of form and function”.

Unjustified agreement
Matt08_03, Matt14_03
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Insufficient AMCC
Stein05_03
The excerpt suggests that “if the hand muscles did not hold the wrist firm in exactly the right way, the power of the finger muscles would be lost…energy would not succeed in reaching

the fingers", observing an effect of insufficient AMCC (lack of desired energy transference across joints).

Stein05_09
The excerpt identifies "overly flexible fingers" as a "disadvantage" that can cause "loss of power", suggesting to focus on "the muscles..[that] make the joint firm or relax it" - a mention of some of the effects of insufficient AMCC and a prescribed solution (more AMCC).

Stein05_10
The excerpt observes that "continually demanded 'looseness' of the wrist is simply not compatible" with "the necessary stability of resistance", and that this "resistance…must be learned in the most finely shaded gradations", via AMCC (e.g., via the "shorter hand muscles surrounding the wrist").

Chi46_80
Ching identifies insufficient AMCC as usually causing "the failure to begin…efficiently", for reasons he expounds thoroughly in adjacent passages (e.g., stability and force-transfer).

Importance of AMCC research
Stein05_31
Steinhausen advises that a "history of piano technique from the physiological viewpoint", spanning from "Diruta…through Liszt, would be a task worthy of praise".

Ort29_13
The excerpt identifies the relaxationist trend as "the salient feature of modern piano pedagogy", which has been responsible for "not a few discrepancies and misconceptions", therefore making necessary a "detailed analysis of the property of muscles" - including, but not limited to, detailed analysis of AMCC.

Neuh73_05
Neuhaus suggests that the study of the physiological mechanics of piano playing will help to achieve "good, correct piano playing".

Neuh73_06
Neuhaus claims that knowledge of physiological mechanics "is of no earthly help for the art of pianoforte playing and, what is more, is to be found almost always among those who lack real knowledge", contradicting Neuh73_05.

Critiques of other approaches
Excerpts are only categorized here if they do not qualify for inclusion elsewhere in the model structure.

Sch36_08
Schultz observes the pervasive "doctrine of relaxation" and its insistence that "a stiff joint is the worst of the technical evils", which has at times been exaggerated to the point that "one derives the impression…that loose joints are the only requirements of a first-rate piano technique".

Chi46_09
Ching warns against "The Relaxation School", which he correctly cautions has "filled the minds of pianists and teachers with the dominant idea that the joints should always, under every possible circumstance, be loose and free from all tension".

Chi46_39
Ching poses a reasonable question about AMCC (here “tension”): “why Nature should present us, not only with the ability to create tension, but also with the instinct to use it” - while critiquing relaxationist theories.

Kay03_01
The excerpt diagnoses the state of many pedagogical treatises as “understocked with objective, factual proofs…commonly in contradiction not only with facts but also…[their] own theoretical position[s]”. The present review corroborates this diagnosis.

Ger07_48
Gerig highly recommends Newman’s The Pianist’s Problems, but present analysis of this work (see New84) suggests that its discussion of AMCC is not recommendable given its unclear terminology.