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When Musical Accompaniment Allows the Preferred Spatio-Temporal Pattern of Movement

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ABSTRACT

A musical accompaniment is often used in movement coordination and stability exercise modalities, although considered obstructive for their fundament of preferred movement pace. This study examined if the rhythmic strength of musical excerpts used in movement coordination and exercise modalities allows the preferred spatio-temporal pattern of movement. Voluntary and spontaneous body sway (70 s) were tested ($N = 20$ young women) in a non-musical (preferred) and two rhythmic strength (RS) musical conditions (Higher:HrRS, Lower:LrRS). The center of pressure trajectory was used for the body sway spatio-temporal characteristics (Kistler forceplate, 100 Hz). Statistics included paired t-tests between each musical condition and the non-musical one, as well as between musical conditions ($p \leq 0.05$). Results indicated no significant difference between the musical and the non-musical conditions ($p > 0.05$). The HrRS differed significantly from LrRS only in the voluntary body sway, with increased sway duration ($p = 0.03$), center of pressure path ($p = 0.04$) and velocity ($p = 0.01$). The findings provide evidence-based support for the rhythmic strength recommendations in movement coordination and stability exercise modalities. The HrRS to LrRS differences in voluntary body sway most possibly indicate that low-frequency musical features rather than just tempo and pulse clarity are also important.

Introduction

Musical accompaniment is documented to enhance performance in endurance exercise modalities [1–3] as well as in muscular strength ones [4]. However, in movement coordination and stability (MCS) exercise modalities (i. e., Pilates), a musical accompaniment is unadvised as obstructive for their fundament of preferred movement pace [5, 6]. The inherent exercise description according to the breathing pattern in MCS modalities [5, 6] postulates the notion of preferred pace during learning and performing the movement. The notion that a musical accompaniment may potentially disrupt rather than benefit the efficiency of performance rests in previous studies. Specifically, music may potentially impair postural tasks [7–9] and distract concentration during coordination and precision tasks [10]. It may also have a musical genre-specific effect on the movement's amount and fluidity [11] as well as its perceived easiness, preciseness, and rhythmicity [12].

The potential incompatibility of musical accompaniment with the preferred movement pace is reasoned on the participant's regulation away from his/her natural periodic pace [13, 14] or movement duration [10]. However, the association of music with pleasure [15] motivates its use in MCS exercise modalities despite its potential contrast to the fundament of one's preferred pace. As such, a musical stimulus of low tempo (< 100 bpm: beats per minute), and low pulse clarity (music without a strong beat) is recommended in relevant textbooks [16]. However, such suggestions appear extrapolated rather than evidence-based, reasoned on the relationship between the propensity to move and rhythmic strength descriptors of the musical signal (i. e., tempo, pulse clarity, event density, spectral flux, low energy) [17–19]. The response of the autonomic nervous system to tempo, which is suppressed parasympathetic and increased sympathetic activation in tempi higher than the normal heart rate during long-lasting passive music listening, also explains the slow tempo recommendation in MCS exercise modalities [20]. However, to the best of our knowledge, there is no previous study documenting that the musical accompaniment used in MCS exercise modalities does allow the fundament of one's preferred movement pace, or does not influence the preferred spatio-temporal movement pattern.

Similar to Burger et al. [14] and Madison et al. [21], we aimed at designing a study of the higher possible ecological validity, in so far as this is allowed in a laboratory situation. To this end, we chose real pre-existing musical excerpts among those used in MCS exercise modalities, accepting the downside [21] that their propensity-to-move properties [22] were not tested. However, this approach made it possible to present the participants with the kind of music that they were familiar with. To further enhance the external validity of our study, the voluntary and spontaneous body sway were selected as movement tasks, reflecting the whole body weight shifting and static balance tasks commonly employed in MCS exercise modalities [23, 24]. Furthermore, the body sway tasks allowed the comparison with previous studies addressing the musical stimulus effect on voluntary [25] or spontaneous [7, 8, 25–29] body sway. The voluntary body sway was of particular interest, because despite the need for voluntary rather than spontaneous body sway in daily activities, the relevant studies appear limited to the influence of discrete (i. e., metronome beats) rather than continuous auditory stimuli [25].

Thus, the purpose of the study was to examine if pre-existing musical excerpts among those commonly used to accompany MCS exercise modalities allow the preferred spatio-temporal pattern of movement during voluntary and spontaneous body sway. Because the preferred movement pace is a fundament of such modalities, we hypothesized that the selected musical stimuli would not significantly alter the spatio-temporal characteristics of the voluntary and spontaneous body sway when compared to a non-musical stimulus condition.

Materials and Methods

Participants

Twenty healthy women participated in the study (▶ **Table 1** shows their characteristics and the inclusion criteria [28, 30–33]). The uHear application (a pure-tone hearing sensitivity test, which runs on iOS devices, iPod, iPhone, and iPad) was used to verify their normal and symmetrical hearing. The study meets the ethical standards described by Harriss et al. [34] and was approved by the University Bioethics Committee. All participants signed informed consent.

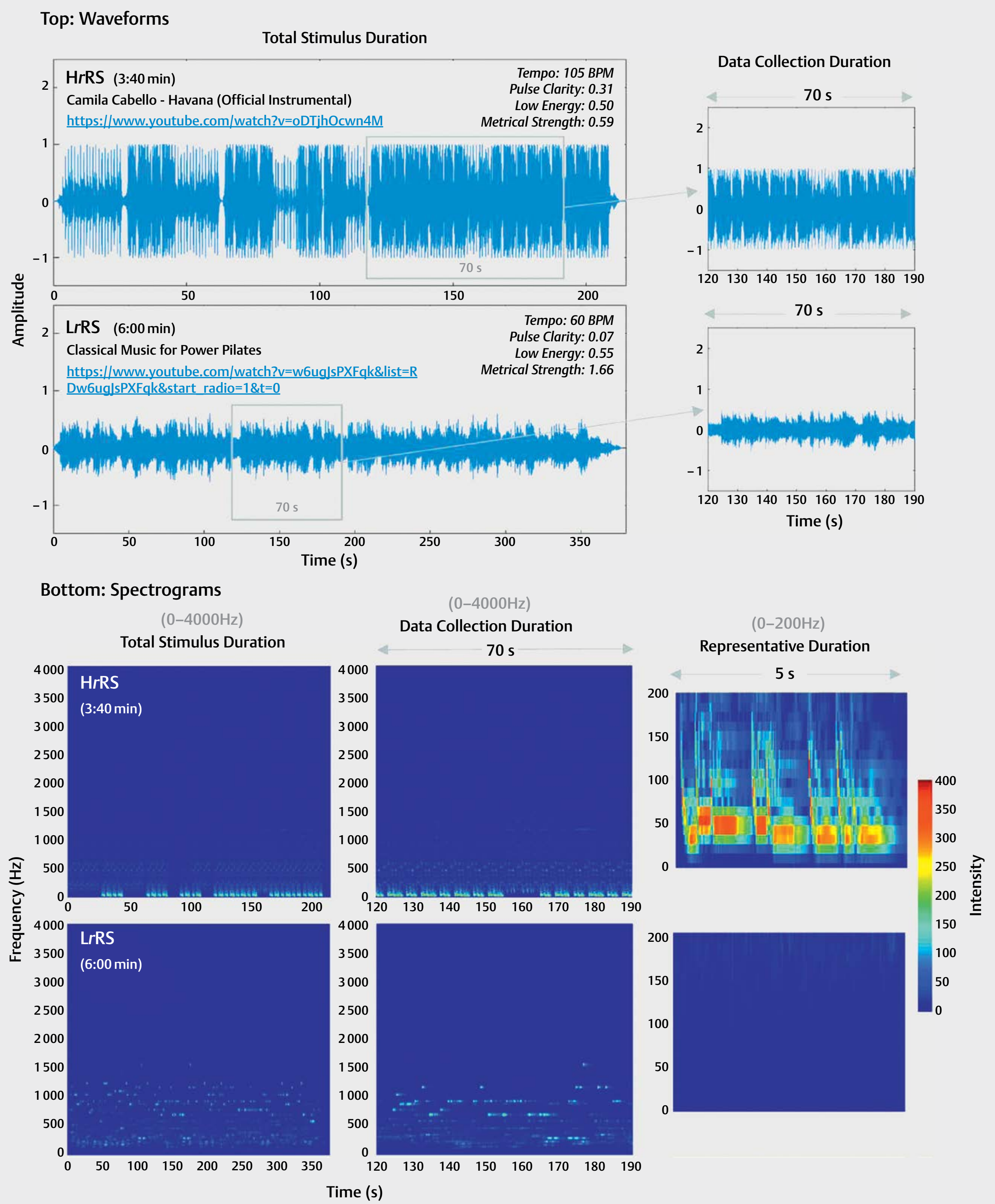
Musical stimuli

As recommended for MCS exercise modalities [16], two musical pieces within the slow to medium tempo range [19] were selected (▶ **Fig. 1**). The pieces were chosen from a list suggested by experienced instructors, who perceptually discriminated them into higher (H*r*RS) and lower (L*r*RS) rhythmic strength (RS) (no specific criteria were provided). They were chosen from among instrumental ones to avoid any physiological [3], mental [35], attentional [36], or emotional [37] influence due to the lyrics. A musical signal analysis (▶ **Fig 1**, ▶ **Fig. 1s**) (Matlab MIRtoolbox, [38]) estimated rhyth-

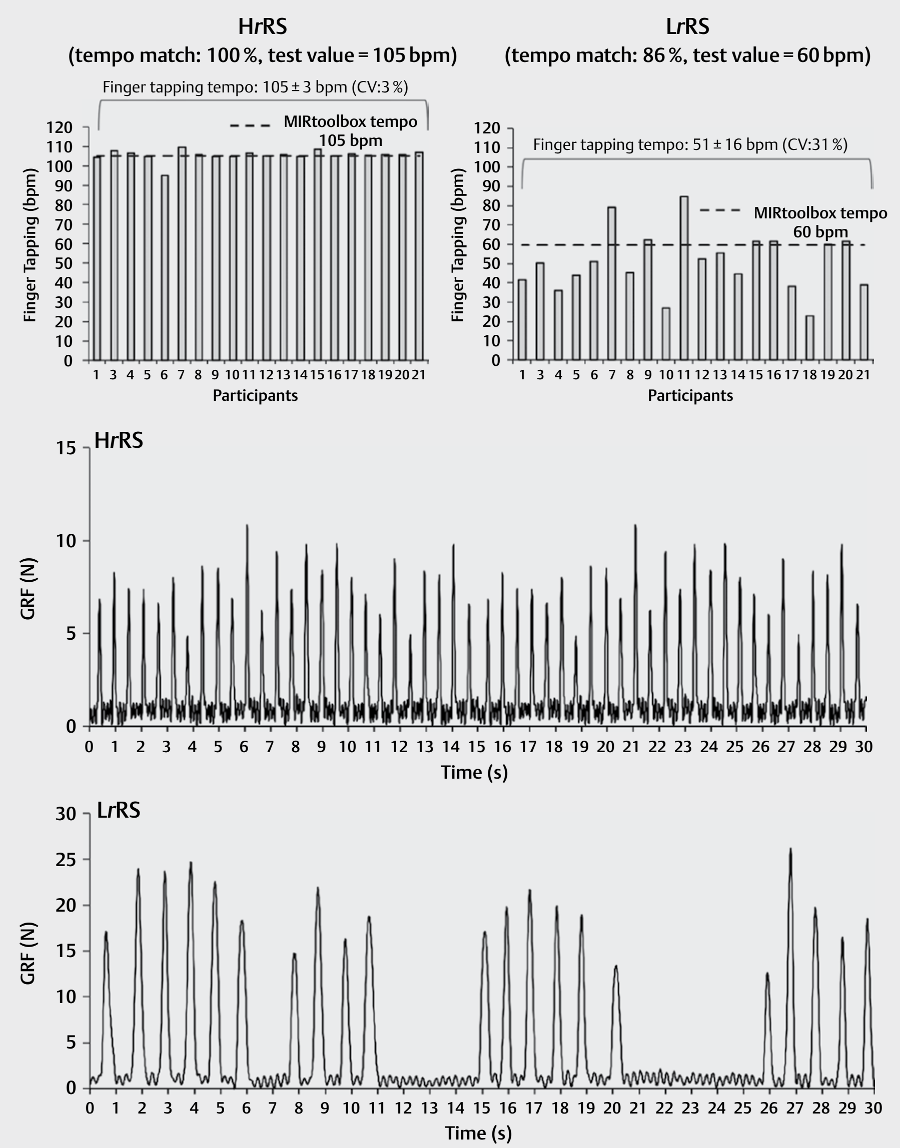
▶ **Table 1** Characteristics (mean ± SD) of the participants (n = 20 women *) and their inclusion criteria.

Characteristics	Mean ± SD	Inclusion criteria **
Age (yrs)	26.0 ± 4.2	Gender (only women), age range (from 20 to 30 yrs) [30], moderate physical activity [31].
Body height (m)	1.72 ± 0.06	Anthropometrics [32]: body height range (from 1.60 to 1.75 m), within the normal range of body mass index (from 18.5 to 24.9 kg/m²).
Body mass (kg)	68.1 ± 10.6	No musical training or experience [28].
Body mass index (kg/m²)	21.2 ± 2.0	No visual, vestibular, auditory, musculoskeletal or neurological disorder [33].

* A sample of 20 subjects was considered adequate for an empirically estimated "smallest expected effect" of d = 0.65 to be detected in "musical versus non-musical" comparisons with a power of at least 80 %, assuming a two-tailed test at α = 0.05 (details in the "Sample Power Analysis" **supplementary material**). ** Inclusion criteria aimed to eliminate potential confounding factors.



▸ **Fig. 1** Waveforms (top) and spectrograms (bottom) of the higher (HrRS) and the lower (LrRS) rhythmic strength (RS) musical stimuli. The information embedded in the waveform panels indicate the values of the musical features associated with RS, extracted through musical analysis (MIRtoolbox 1.7 software [38]). Details of the relevant MIRtoolbox routines used to extract the specific musical features are provided in the supplementary material under the title MIRtoolbox signal analysis. **Top left:** Total duration of each musical stimulus. **Top right**: Data collection duration (70 s) of each musical stimulus. **Bottom left:** Total duration waveform of each musical stimulus across the 0–4000 Hz frequency band. **Bottom middle:** Waveform of each musical stimulus across the 0–4000 Hz frequency band for the data collection duration (70 s). **Bottom right:** Indicative 5 s waveform of each musical stimulus enlarged for the 0–200 Hz frequency band (the frequency band associated with the affordance of a musical stimulus to affect body movement [13, 46, 47, 56]) illustrating the greater flux (intensity fluctuation) in the HrRS than the LrRS musical stimulus.



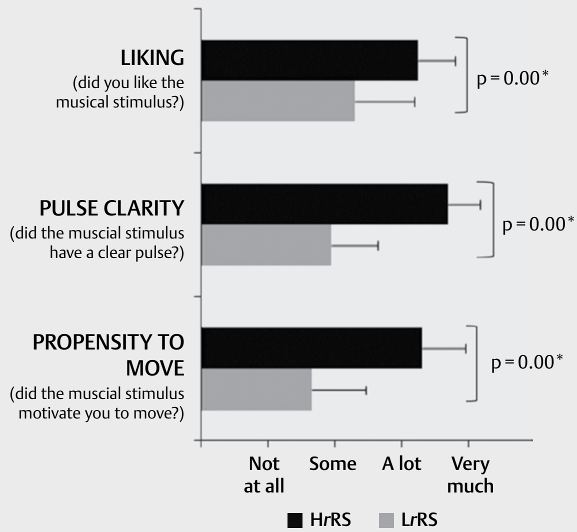
▶ **Fig. 2** **Top:** Finger tapping tempo in the higher (HrRS) (left) and the lower (LrRS) (right) rhythmic strength musical stimuli. The mean ± SD as well as the percentage coefficient of variability (CV %: (SD/mean) × 100) of the finger tapping tempo are noted. The tempo match between finger tapping and MIRtoolbox analysis is noted (HrRS:100 % and LrRS:86 %) based on their non-significant difference in HrRS (p = 0.22) and their significant one in LrRS (p = 0.01) (one-sample test statistical procedure of SPSS 25.0 at p ≤ 0.05, using as test value the MIRtoolbox tempi, that is 105 bpm for HrRS and 60 bmp for LrRS). **Center and bottom:** vertical ground reaction force (GRF) curves for the 10 consecutive finger-tapping cycles of a representative participant in the HrRS (center) and the LrRS (bottom).

mic strength features reported to influence body sway [7, 13, 17–19, 26, 27, 39]. In both musical stimuli, data collection concerned the 70 s from 2:00 to 3:10 min (voluntary and spontaneous body sway).

For a perceptual tempo estimation [14] before data collection, the participants tapped their index finger on a force plate surface for 30 s at a 1:1 ratio with the musical beat (▶ **Fig. 2**) (2:00–2:30 min in both musical stimuli; they were instructed not to look at their finger to avoid visual interference). The finger tapping tempo differed significantly from the L*r*RS (p = 0.01) but not from the H*r*RS (p = 0.22) one (▶ **Fig. 2**). The individual ratings (after data collection, ▶ **Fig. 3**) indicated the perception of significantly different rhythmic strength indices between H*r*RS and L*r*RS (pulse clarity, feeling of liking and propensity to move [14, 28]).

Data collection procedure

The body sway spatio-temporal characteristics were assessed through the center of pressure (CoP) recordings (Kistler force plate 60 cm × 40 cm × 3.5 cm, Type: 9286AA, sampling at 100 Hz, BioWare version 3.2.6 data acquisition and analysis software; Kistler, Winterthur, Switzerland). MATLAB 2019b software (MathWorks,



▶ **Fig. 3** The mean (SD) of the participants ratings to the 3 item questionnaire regarding their feeling of liking, perception of pulse clarity, and propensity to move for two musical stimuli of higher (H*r*RS–black bars) and lower (L*r*RS–grey bars) rhythmic strength (RS). * Significance of difference at p ≤ 0.05 (Wilcoxon signed-Rank test, SPSS 25.0).

Natick, MA, USA) was used to calculate all variables inserted in statistical analysis.

With their arms along the body and eyes open, the participants performed trials of whole-body voluntary anteroposterior sway (verbal instruction for an ankle-restrained sway, no hip or neck flexion, 70 s data collection), as well as of spontaneous body sway (relaxed upright stance, no instruction to remain as still as possible, 70 s data collection), in three conditions (balanced combination of condition order): without a musical stimulus (non-musical condition, natural sway frequency) and with two musical stimuli (musical conditions, no instruction to synchronize with the musical stimuli, wireless noise-minimizing headphones [40], self-adjusted volume at individual comfort level (60 to 80 dB)). To minimize any differential effect due to visual information [41] or gaze fixation [42], they were all instructed to fixate their gaze at a standardized target (black cross 6 × 6 cm, eye level, 2 m in front of them, natural head posture). To ensure the same feet repositioning across trials, the feet perimeter was traced on a piece of paper secured on the force plate (barefoot to eliminate footwear variance, full contact with the force plate, parallel at preferred width and orientation). A reliability protocol indicated 2 trials as adequate for excellent to fair reliability [43] in the CoP path length across all conditions (▶ **Fig. 4**, ▶ **Table 1s**). Previous studies also indicate 2 trials as adequate for excellent reliability [44, 45]. Thus, 2 trials were decided in all conditions, with 1 min rest between them.

Data analysis

In the voluntary body sway, the first 5 sways were excluded to avoid the trial initiation transition [28], and the next 10 sways were used for data extraction (▶ **Fig. 5**). In the spontaneous body sway, also to avoid the trial initiation transition [28], the first 5 s were omitted, and the next 60 s were used for data extraction (▶ **Fig. 5**). All voluntary body sways demonstrated clear anterior and posterior periodic peaks, and the time between two consecutive anterior peaks defined the single sway duration (s) (▶ **Fig. 5**). After calculating the duration of each one of the 10 retained sways, their mean value defined the sway duration variable (s), and the percentage (%) of their standard deviation to their mean defined the body sway temporal variability, an estimate of postural control with [28, 46] or without [47, 48] a musical stimulus.

The following spatial CoP variables were extracted for the voluntary body sway (anteroposterior CoP path of the 10 sways retained for analysis) and the spontaneous one (anteroposterior and mediolateral CoP path during the 60 s retained for analysis): CoP path length (cm), CoP path variability (%) (standard deviation of the CoP path length divided by its mean and multiplied by hundred), CoP path range (cm) (anterior to posterior peak distance), CoP path velocity (cm/s) (CoP path length divided by the 10 sways' duration and the 60 s duration, in the voluntary and the spontaneous body sway, respectively), and CoP area (cm^2) (95 % confidence ellipse fitting). For the voluntary-only body sway, the maximum anterior and posterior CoP displacement (maximum peak, respectively) (cm) was also estimated. For each variable, the two trial averaged value was included in statistics.

Statistical analysis

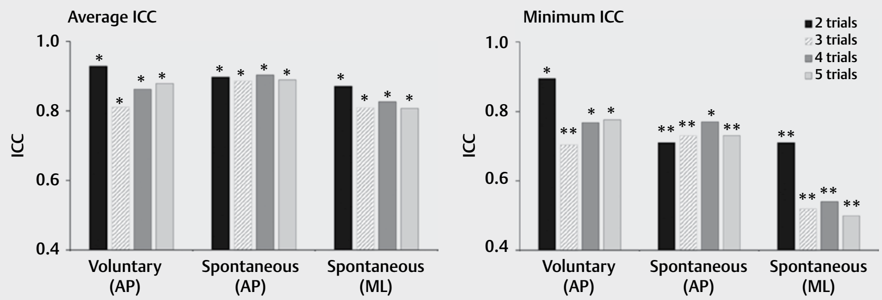
Separately in the voluntary and the spontaneous body sway, paired t-tests were used to compare the non-musical condition to each of the musical ones, and the two musical conditions between them (SPSS v.25.0, IBM Corp., Armonk, NY, USA) ($p \leq 0.05$). For each variable, the 95 % confidence interval of its mean value in each condition, and the Cohen's d effect size of the between-condition comparisons were also computed.

Results

In the voluntary (▶ **Table 1**) as well as in the spontaneous (▶ **Table 2**) body sway, none of the CoP variables demonstrated a significant difference between the musical and the non-musical conditions ($p > 0.05$). In the voluntary body sway, the H*r*RS induced a shorter sway duration ($p = 0.03$), a longer CoP path ($p = 0.04$), and a higher CoP velocity ($p = 0.01$) compared to the L*r*RS one (▶ **Table 1**), with no significant differences in the spontaneous body sway ($p > 0.05$) (▶ **Table 2**).

Discussion

This study examined if pre-existing musical excerpts among those commonly used in MCS exercise modalities allow the preferred body sway spatio-temporal pattern. The results support our hypothesis and show that indeed, regardless of their rhythmic strength, none of the two musical stimuli altered the preferred voluntary or spontaneous body sway spatio-temporal pattern. The purposeful use of musical stimuli among those commonly used in MCS exercise modalities [14, 21], rather than a casual stimuli selection, denotes an ecological approach that may contribute to external validity. The body sway task that reflects the nature of many



▶ **Fig. 4** Average and minimum per body sway intraclass correlation coefficients (ICC) for the CoP path, in the 2, 3, 4, and 5 trials pilot reliability protocol. AP and ML: anteroposterior and mediolateral direction, respectively. Reliability ratings [43]: * Good to excellent: r > 0.75, * * moderate to good: r = 0.50–0.75, small: r = 0.25–0.50, little or no correlation: r = 0.00 – 0.25.

periodic bodyweight shifting or standing (upright, leaning) balance tasks employed in MCS exercise modalities [23, 24] may also add to external validity ▶ **Table 3**.

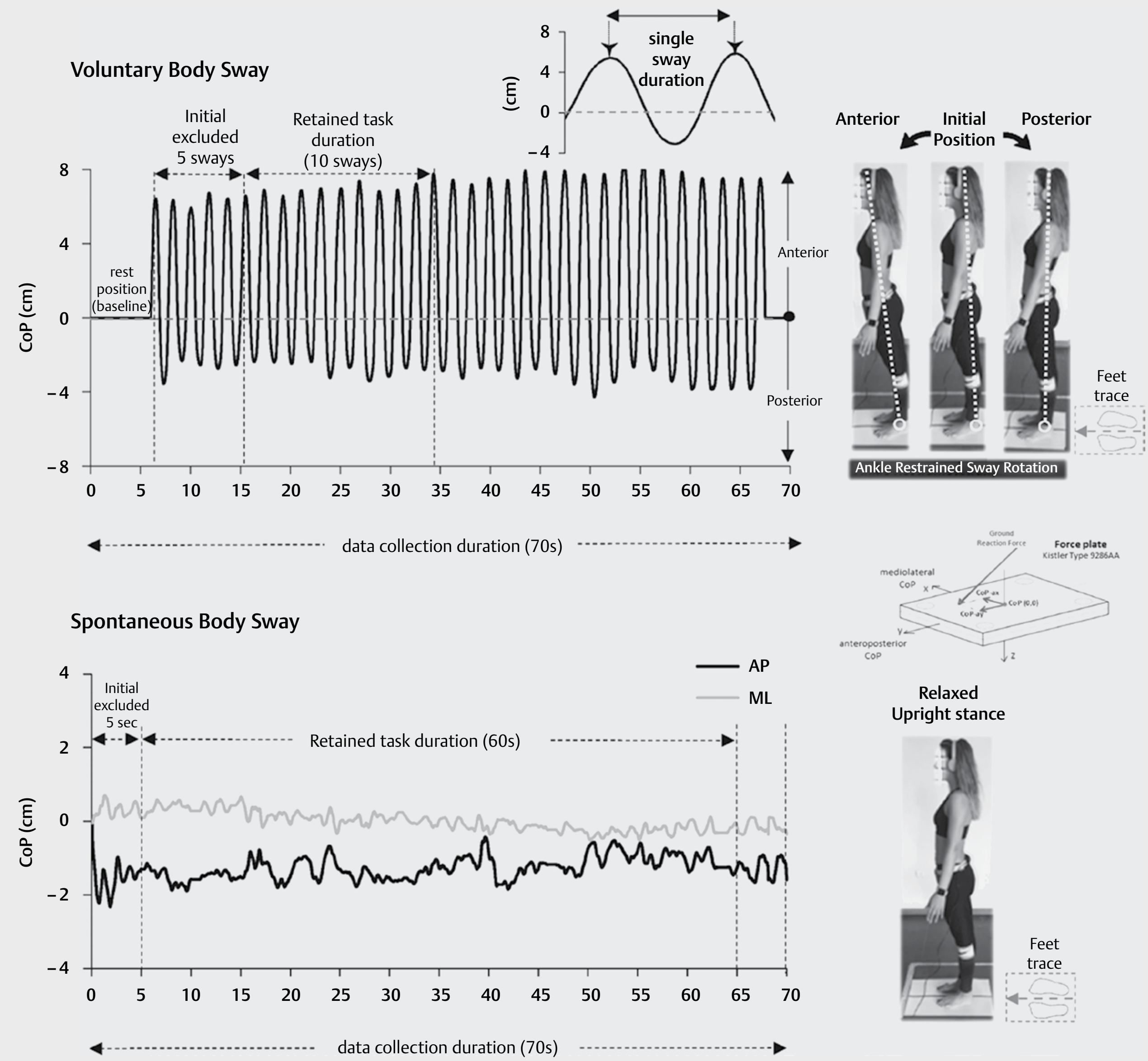
The main research body focuses on the ability of a musical stimulus to affect body sway (negatively [7–9] or positively [25, 26, 28]). Thus, despite the precedent for spontaneous body sway [27, 29], one may be surprised by the rationale concerning the inability of musical stimulus to affect movement. Such variable findings may reflect the inherent redundancy of possible strategies to generate a stable stance that may mask or void the auditory effect [49]. The affordance of a musical stimulus to influence the spatio-temporal body sway measures associates with its features [7, 13, 14, 17, 26, 27]. The rhythmic strength features (tempo, pulse clarity, event density, flux, low energy) relate to the level as well as to the directional influence of a musical stimulus [7, 13, 26, 27].

In MCS exercise modalities, a musical accompaniment is considered to obstruct their fundament of preferred movement pace [5, 6]. However, the association of music with pleasure [15] motivates its use; in such a case, a low tempo/low pulse clarity musical background is suggested [16]. Nevertheless, the relevant recommendations appear extrapolated rather than evidence-based, reasoned on the capacity of rhythmic strength descriptors to increase the propensity to move [17–19]. Such relationships indicate the high pulse clarity as favoring the temporal regulation of periodic movements to the underlying musical pulse periodicities [13, 14, 50], as well as increasing the amount, speed, and spatial effect of a musical stimulus [13, 14]. The lower than 100 bpm limit in MCS exercise modalities indicates a tempo slower than the one optimizing the propensity to move (120 bpm) [23, 39], most likely due to its coincidence with the well-established natural tempo of human movement in gait [51, 52] and finger tapping [53] studies. Tempi lower than 100 bpm may favor movement smoothness, coordination, and stability [39, 54, 55], most likely because they drive the autonomic nervous system at activation levels lower than the natural ones [20, 54]. However, such notions need to be tested in protocols focused on the propensity not to move, rather than inferred from studies on the propensity to move.

The H*r*RS to L*r*RS differences in voluntary body sway may relate to the slight exceedance of the H*r*RS tempo (5 bpm) over the suggested one for MCS exercise modalities (< 100 bpm [16]). However, it may also indicate that when a similar effect is intended through long-lasting passive listening (as in MCS exercise modalities), the overall rhythmic strength should be considered rather than just slow tempo and low pulse clarity. In this line of thinking, the H*r*RS' more intense rhythmic features in the low-frequency range most likely underlie its body sway differences with L*r*RS [13, 46, 56, 57]. People appear to align their movements to low-pitched rhythms [13, 46, 56] independently of movement tempi [46], with the strong rhythmic structures in low frequencies enhancing body movements [13, 56].

Interestingly, even though not instructed to sway with the music, the voluntary body sway duration in H*r*RS was coupled with the musical phrase (8 beats), corroborating earlier work on the relation between metrical levels and the propensity to move [28]. The beat and the bar level are the most essential metrical levels [50, pp. 105–106] for movement association to tempo [39]. In the fitness music industry, the typical metrical structure is a bar consisting of four beats (notated at the quarter-note level), with two bars creating the sense of a musical phrase [16]. Thus, the monotonic relation of inertial load dynamics to natural frequency may explain the coupling of the whole body natural frequency (0.25 Hz [25] to a global (2 bars) rather than a local (beat) timescale, as typically occurs when a low inertial load renders a higher natural frequency (i. e., 1.5–2.5 Hz of finger tapping [58]).

The voluntary body sway results are not without limitations, as these were obtained from an ankle-restrained body rotation rather than a free-form body sway, which could be argued as higher in external validity. However, a free-form body sway not only does not reflect the nature of movements in MCS exercise modalities but could also induce uncontrolled influence on postural stability [28, 45]. Specifically, the ankle restraint aimed to avoid confounding factors such as both hip and ankle strategy [25], segmental movements (head and upper limb) due to a differential influence of musical features other than tempo and pulse clarity [13], or interparticipant differences concerning the timescale embodiment of pulse periodicities [14]. Such factors may relate to the individual intrinsic variability that appears to differentiate the degree that auditory rhythms (particularly when low-pitched) affect the movement tempo and amplitude (lower/higher influence in more/less intrinsic movement variability) [46]. The suitability of the finger-



▶ **Fig. 5** Voluntary (top) and spontaneous (bottom) body sway CoP trajectories for a representative participant. The following are indicated for the voluntary and the spontaneous body sway, respectively: the whole data collection duration (70 s in both), and the initial excluded data to avoid the trial initiation transition (5 sways and 5 s) as well as the retained task duration (10 sways and 60 s). The ankle-restrained rotation during the voluntary body sway and the relaxed stance during the spontaneous sway are also illustrated by one of the participants.

tapping task to estimate the subjective perception of pulse clarity could also be argued as not having a straightforward relation with whole-body sway due to their distinct natural frequencies [25, 58]. However, a finger tapping test was also used for lateral free-form body sway, which is more complex and of more variable degrees of freedom than the ankle-restrained anteroposterior body sway of this study [14].

In conclusion, the main finding of the present study was that the real, pre-existing musical excerpts commonly used in MCS exercise modalities did not regulate the spatio-temporal pattern of the voluntary and spontaneous body sway away from the preferred one. Our results provide evidence-based support for the low tempo/low pulse clarity recommendations in MCS exercise modalities, aiming to ensure their fundament for movement learning and performance, citing the preferred movement pace. They also indicate that when a similar effect is intended through long-lasting passive listening (as in MCS exercise modalities), the low-frequency features rather than just tempo and pulse clarity should also be considered. Thus, if instructors familiarize themselves with musical signal analysis, they may purposefully take them into account when selecting a musical accompaniment for MCS exercise modalities.

▶ **Table 2 Voluntary body sway. Top:** Mean ± SD of the CoP variables for the non-musical stimulus (NM) condition as well as for the two musical stimuli of higher (HrRS) and lower (HrRS) rhythmic strength. The significance (p values) of the comparisons between conditions is also presented. **Bottom:** Lower and upper bound of the mean 95 % confidence interval and Cohen's d effect size.

Variables	**NM**	**HrRS**	**HrRS**	**NM vs. HrRS**	**NM vs. HrRS**	**HrRS vs. LrRS**
	Mean ± SD			**Paired t-tests p values**		
Sway duration (s)	4.36 ± 2.04	4.01 ± 1.97	4.54 ± 2.34	0.105	0.781	0.031 *
Sway duration variability (%)	9.44 ± 2.35	9.18 ± 2.62	9.50 ± 2.36	1.000	1.000	1.000
CoP path (cm)	288.6 ± 63.1	295.9 ± 57.1	282.7 ± 56.1	0.334	1.000	0.046 *
CoP path variability (%)	54.99 ± 13.71	55.17 ± 12.11	55.92 ± 11.45	1.000	1.000	1.000
CoP velocity (cm/s)	8.19 ± 2.65	9.13 ± 2.84	7.90 ± 2.91	0.055	1.000	0.012 *
CoP range (cm)	17.05 ± 2.74	17.49 ± 2.40	16.83 ± 2.77	0.371	1.000	0.135
CoP area (cm²)	47.34 ± 15.64	47.84 ± 19.21	43.99 ± 16.35	1.000	0.406	0.937
Maximum anterior CoP displacement (cm)	10.13 ± 2.99	10.20 ± 2.02	10.39 ± 2.33	1.000	1.000	1.000
Maximum posterior CoP displacement (cm)	5.10 ± 1.80	5.12 ± 1.73	5.01 ± 1.66	1.000	1.000	1.000
	95 % confidence interval Lower bound–Upper bound			**Cohen's d effect size**		
Sway duration (s)	(3.40–5.31)	(3.1–4.93)	(3.44–5.63)	0.17	0.08	0.24
Sway duration variability (%)	(8.34–10.53)	(7.95–10.41)	(8.4–10.6)	0.10	0.03	0.13
CoP path (cm)	(259.0–318.5)	(269.2–322.6)	(256.5–309.0)	0.12	0.10	0.23
CoP path variability (%)	(48.57–61.41)	(49.5–60.84)	(50.56–61.28)	0.01	0.07	0.06
CoP velocity (cm/s)	(6.95–9.43)	(7.81–10.46)	(6.53–9.26)	0.35	0.10	0.43
CoP range (cm)	(15.77–18.33)	(16.37–18.61)	(15.53–18.12)	0.17	0.08	0.26
CoP area (cm²)	(40.02–54.66)	(38.85–56.83)	(36.33–51.64)	0.03	0.21	0.22
Maximum anterior CoP displacement (cm)	(8.73–11.53)	(9.26–11.15)	(9.3–11.49)	0.03	0.10	0.09
Maximum posterior CoP displacement (cm)	(4.26–5.94)	(4.31–5.93)	(4.23–5.79)	0.01	0.05	0.07

* Significance of difference at p ≤ 0.05. Cohen's d effect size interpretation: 0.2 = small, 0.5 = medium, and 0.8 = large. If d < 0.02, the difference is negligible even if it is statistically significant.

▶ **Table 3 Spontaneous body sway. Top:** Mean ± SD of the CoP variables for the non-musical stimulus (NM) condition as well as for the two musical stimuli of higher (HrRS) and lower (HrRS) rhythmic strength. The significance (p values) of the comparisons between conditions is also presented. **Bottom:** Lower and upper bound of the mean 95 % confidence interval and Cohen's d effect size.

Variables		**NM**	**HrRS**	**HrRS**	**NM vs. HrRS**	**NM vs. HrRS**	**HrRS vs. LrRS**
		Mean ± SD			**Paired t-tests p values**		
CoP path (cm)	AP	30.89 ± 9.44	30.63 ± 9.13	31.21 ± 8.09	1.000	1.000	0.964
	ML	20.05 ± 9.64	18.01 ± 6.46	19.11 ± 6.88	0.766	1.000	0.756
CoP path variability (%)	AP	15.09 ± 15.46	13.89 ± 11.27	19.61 ± 24.04	1.000	0.262	0.362
	ML	29.38 ± 18.52	31.31 ± 22.01	33.74 ± 26.27	1.000	1.000	1.000
CoP velocity (cm/s)	AP	0.51 ± 0.16	0.51 ± 0.15	0.52 ± 0.13	1.000	1.000	0.964
	ML	0.33 ± 0.16	0.30 ± 0.11	0.32 ± 0.11	0.766	1.000	0.756
CoP range (cm)	AP	2.16 ± 0.57	2.19 ± 0.50	2.54 ± 1.01	1.000	0.456	0.396
	ML	1.25 ± 0.66	1.26 ± 0.50	1.28 ± 0.50	1.000	1.000	1.000
CoP area (cm²)		2.37 ± 2.30	2.26 ± 1.38	2.33 ± 1.82	1.000	1.000	1.000
		95 % confidence interval Lower bound–Upper bound			**Cohen's d effect size**		
CoP path (cm)	AP	(26.47–35.31)	(26.35–34.90)	(27.42–35.00)	0.03	0.04	0.07
	ML	(15.54–24.56)	(14.99–21.03)	(15.89–22.33)	0.25	0.11	0.17
CoP path variability (%)	AP	(7.85–22.32)	(8.62–19.17)	(8.36–30.87)	0.09	0.22	0.30
	ML	(20.71–38.04)	(21.01–41.61)	(21.45–46.04)	0.10	0.19	0.10
CoP velocity (cm/s)	AP	(0.44–0.59)	(0.44–0.58)	(0.46–0.58)	0.04	0.03	0.07
	ML	(0.26–0.41)	(0.25–0.35)	(0.26–0.37)	0.24	0.10	0.17
CoP range (cm)	AP	(1.90–2.43)	(1.96–2.43)	(2.07–3.02)	0.05	0.46	0.44
	ML	(0.94–1.56)	(1.04–1.50)	(1.05–1.52)	0.03	0.06	0.03
CoP area (cm²)		(1.30–3.45)	(1.62–2.91)	(1.48–3.18)	0.06	0.02	0.04

* Significance of difference at p ≤ 0.05. Cohen's d effect size interpretation: 0.2 = small, 0.5 = medium, and 0.8 = large. For example, if d < 0.02, the difference is negligible even if it is statistically significant.

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Conflict of Interest

The authors declare that they have no conflict of interest

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