Swiss Ball Jump to stimulate lower limb extension velocity: A proof of concept

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Headline

To stimulate velocity during a jump, the lower limb extension velocity must be higher than during a squat jump (SJ) or a countermovement jump (CMJ) performed at body weight or a very close load (1,2,3,4). This condition can be attained through exercises using arm assistance (5), elastic bands (6,7), or devices that completely remove body weight by eliminating the effects of gravity, such as a low-friction rolling board (8) or an instrumented horizontal leg press ergometer (9). However, to our knowledge, no study has yet investigated the use of a swiss ball to assist vertical jumps and to induce such high-velocity push-off conditions.

Aim

Our main objective was to present and demonstrate a reliable exercise modality designed to stimulate lower limb extension velocity: the Swiss Ball Jump (SBJ). We also aimed to compare this modality with other already existing exercises, such as the CMJ with arm assistance and the SJ with elastic bands assistance, in order to determine precisely its effectiveness in stimulating the capacity to produce velocity during jumps.

Methodology

Subjects

Nine men (age: 22.6 ± 1 year, height: 1.75 ± 0.04 m, body mass: 69.6 ± 11.9 kg) voluntarily participated in this cross-sectional study after giving their written consent. All procedures were conducted in accordance with the Declaration of Helsinki. All participants were physical education and sports science students who were in good health, practiced regularly a physical activity (strength and/or endurance training, etc.) and did not present any musculoskeletal pain or injury during the study.

Study design

The present study was conducted using a cross-sectional experimental design. First, a familiarization session was conducted to familiarize the participants with the testing procedures and to correct the technical execution of the exercises. This session was also used to measure the vertical push-off distance (hpo), determined as the difference in lower limb length between the take-off position and the preferential starting position in SJ (10), both measured using a tape (11). Then, the first test session was conducted. It started with a standardized warm-up of 10 minutes, including 3 minutes of pedaling, joint mobility exercises, and jumps with and without load. Next, the participants performed the exercise modalities in a randomized order:

The SJ_0 condition consisted of SJ performed at body weight, with a lightweight stick (Sveltus, France). The SJ_{60} condition consisted of SJ performed with an additional load corresponding to 60% of body weight, with an Olympic bar and weight discs (Sveltus, France). The SJ_{elastic} consisted of SJ performed with an elastic assistance corresponding to a reduction of 38.3% ± 7.3% of body weight, with two elastic bands (Sveltus, France) attached to the upper bar of the squat cage and positioned under the participants' thighs, generating a traction force of 235 to 295 N during the movement. When they were ready, the participants bent their knees to reach the comfortable starting position that had previously been measured, marked by a physical reference point (box or elastic band) placed at this height. After maintaining this position for approximately 2 seconds, they performed a ballistic jump, applying maximum force as fast as possible to jump for maximum height, while keeping their chest upright. Countermovements were forbidden, and carefully checked visually in real time and verified a posteriori by video analysis. The participants were also asked to maintain the same position at take-off and landing, i.e., with extended legs and foot plantar flexion.

The CMJ_{wa} condition consisted of CMJ performed with an arms assistance. The participants were standing and, when they were ready, they started a downward movement, i.e., they bent their knees to reach the comfortable starting position that had previously been measured, marked by a physical reference point (box or elastic band) placed at this height, and then immediately performed a ballistic jump, using the momentum generated by the descent. The use of the arms was obligatory for accompanying and accelerating the jumping movement. The participants were also asked to maintain the same position at take-off and landing, i.e., with extended legs and foot plantar flexion.

The SBJ condition is presented in Figure 1. The participants were seated on the front of a swiss ball of 65 centimeters in diameter (Domyos, a Decathlon product, France), inflated to an internal pressure of 16 PSI (Pound per Square Inch, ib/in^2), which is equivalent to 1.1 bar, with a knee flexion of approximately 90°. When they were ready, they did two or three bounces without leaving the swiss ball with their buttocks, to generate energy, then immediately performed a ballistic jump during the upward phase. The use of the arms was obligatory for accompanying and accelerating the jumping movement. The participants were also asked to maintain the same position at take-off and landing, i.e., with extended legs and foot plantar flexion.

Finally, for all exercise modalities (SJ_0, SJ_{60}, SJ_{elastic}, CMJ_{wa}, and SBJ), any trial that did not respect these instructions was canceled and restarted. The participants performed two trials, and a third could be required if the difference between the first two exceeded 5%. The best trial (i.e., the performance associated with the highest mean velocity during the push-off phase) was selected for the data analysis. Note that a 2-minute rest period was respected between every jump to ensure sufficient recovery.

This study was also conducted using a test-retest experimental design. A second test session was conducted, during which the participants performed the SBJ exercise under the same conditions as in the first session (evaluators, equipment, protocol, and instructions). It was carried out on D+3, at the same time of the day (± 1 hour), in order to limit variations due to circadian rhythms.

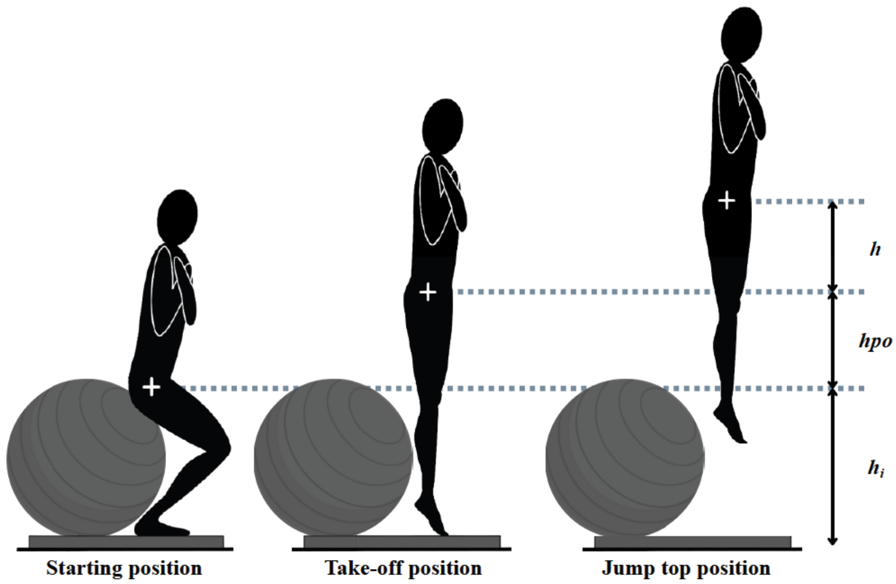

Fig. 1. Experimental setup diagram showing the starting position, the take-off position, and the jump top position during a Swiss Ball Jump. With h_i: Initial center of mass height in starting position; hpo: Vertical push-off distance, i.e., the displacement of the center of mass during the push-off phase; h: Jump height, i.e., the displacement of the center of mass during the flight phase.

Measurements and data analysis

Each exercise modality (SJ_0, SJ_{60}, $SJ_{elastic}$, CM_{wa}, and SBJ) was performed on a force plate (K-Deltas, a Kinvent product, France), with a sampling frequency of 1000 Hz. The raw signal was recorded, filtered using a low-pass filter (Butterworth at 15 Hz), and then analyzed in an Excel file (Office, Microsoft, 2025). The instantaneous ground reaction force (GFR (t)) was used to calculate the instantaneous vertical acceleration $(a(t))$ of the center of mass. Then, the instantaneous vertical velocity $(v(t))$ was obtained by integrating the acceleration over the time, considering the integration constant equal to zero due to the initial velocity being null. Then, the instantaneous vertical position $(p(t))$ of the center of mass was obtained by integrating the velocity over time, considering the integration constant equal to zero due to the initial position being null. For the instantaneous vertical power $(P(t))$, it was calculated as the product of the force and velocity at each instant.

Finally, the force, velocity and power signals were averaged over the push-off phase, defined as the time interval between the start of the push-off (corresponding to the first increase in the force signal above the threshold of 20 N for the exercise conditions (SJ_0, SJ_{60}, $SJ_{elastic}$), or the first increase in the velocity signal above the threshold of 0,05 m/s for the exercise conditions (CM_{wa}, and SBJ)) and the take-off (when the force dropped to zero). The jump height (h) was determined as the difference between the maximum vertical displacement of the center of mass during the flight phase and the center of mass height in take-off position.

Statistical analysis

Statistical analyses were performed using JASP software (version 0.95.2 ; JASP Team, 2025) to describe the variables of mean force, velocity, power, jump height and hpo obtained during each exercise modality. The results are presented as mean ± standard deviation (sd), individual distributions and effect sizes (ES), determined using the Cohen's d index, with a 95% confidence interval (CI) (12,13). The practical inferences used are interpreted according to these thresholds: $d < 0.2$ = insignificant effect, $0.2 < d < 0.6$ = small effect, $0.6 < d < 1.2$ = moderate effect, $1.2 < d < 2$ = large effect, $2 < d < 4$ = extremely large effect.

Regarding intra- and inter-session reproducibility, the relative reliability was evaluated using the intra-class correlation coefficient (ICC). The ICC scores are interpreted like this: $0 < ICC < 0.20$ = poor reliability, $0.21 < ICC < 0.40$ = passable reliability, $0.41 < ICC < 0.60$ = moderate reliability, $0.61 < ICC < 0.80$ = good reliability, $0.81 < ICC < 1$ = excellent reliability. The absolute reliability was evaluated using the coefficient of variation (CV) and was considered acceptable if it was lower than 10% (14). To complete this analysis, the level of concordance between measurements across trials and sessions was evaluated using Bland and Altman plots, represented by the mean bias and the 95% limits of agreement (15,16).

Results

The typical curves of force, speed, and power over the time for an athlete performing a SBJ are presented in Figure 2 to illustrate the different key zones of the movement. The descriptive statistics for the variables of mean force, velocity, power and jump height, comparing the SJ_0 condition with the other exercise modalities (SJ_{60}, $SJ_{elastic}$, CM_{wa}, and SBJ), and those comparing SBJ with CM_{wa} and $SJ_{elastic}$, are presented in Figure 3. The intra- and inter-session reproducibility of the mean force, velocity, power, jump height and hpo variables obtained during the SBJ condition is presented in Table 1, Table 2 and in Figure 4.

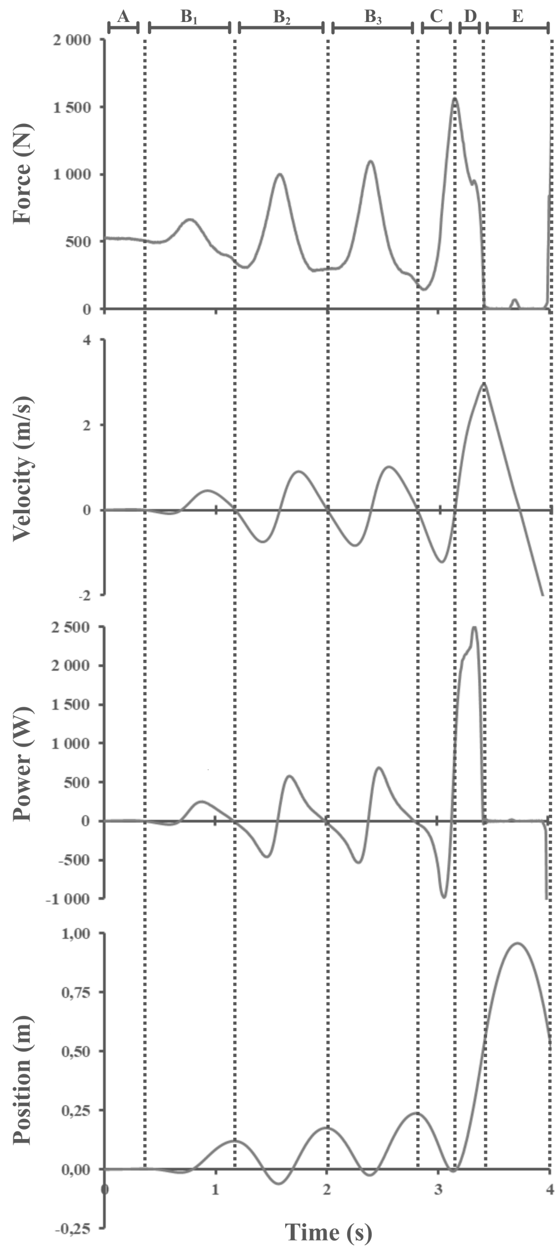

Fig. 2. **Signals of force, velocity and power over time for a typical athlete performing a Swiss Ball Jump.**
• A = Preparatory phase: The athlete is in a seated position and immobile on the swiss ball.
• $B_{(1,2,3)}$ = Rebond phases : The athlete performs three consecutive rebounds on the swiss ball, with their buttocks remaining in constant contact with it.
• C = Eccentric phase: The athlete is in the downward phase of the movement, characterized by a compression of the swiss ball and an eccentric contraction of the lower limbs.
• D = Push-off phase: The athlete is in the upward phase of the movement, characterized by a decompression of the swiss ball and an eccentric contraction of the lower limbs.
• E = Flight phase: The athlete leaves the ground and becomes in the air.

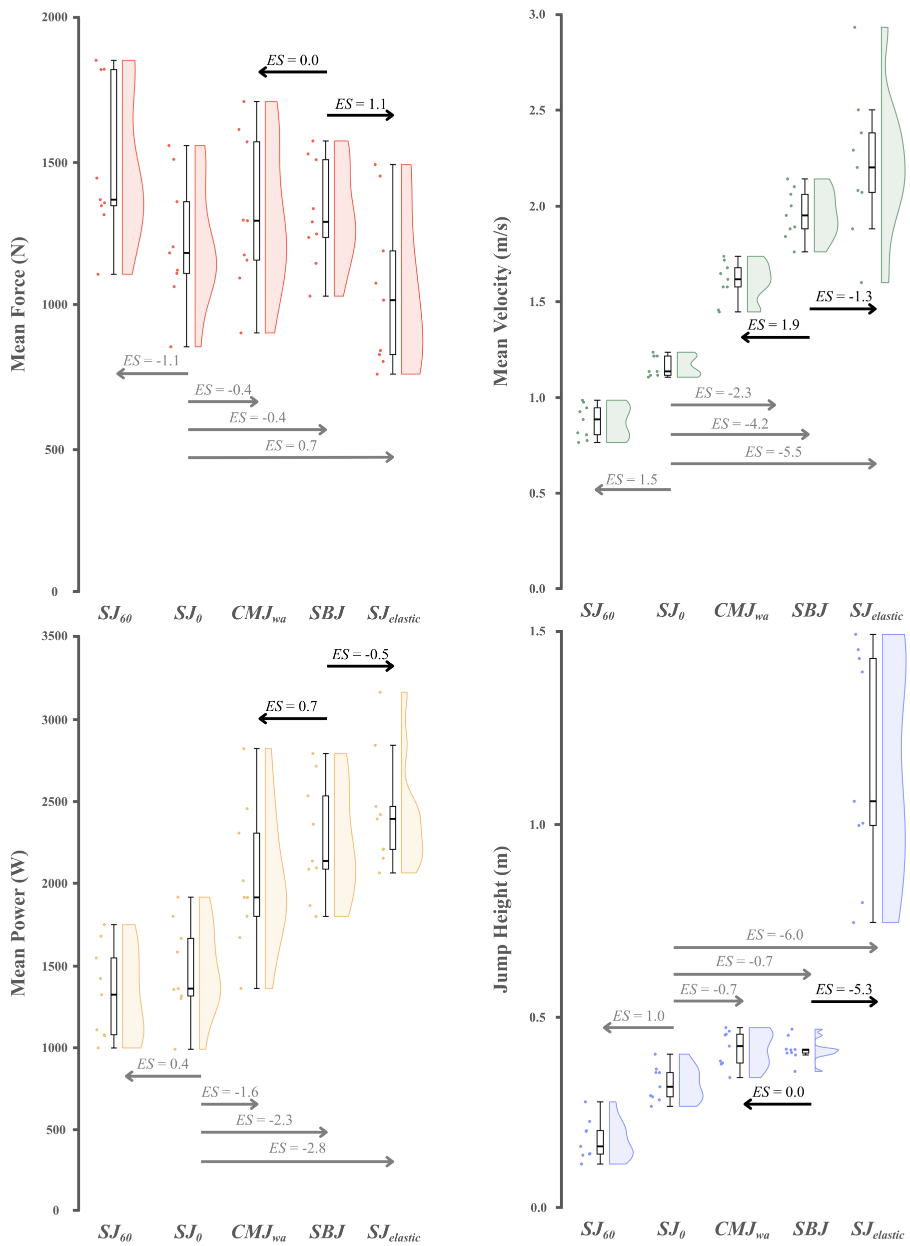

Fig. 3. **Individual distributions, median, quartiles, minimum and maximum values are shown. Effect sizes (ES), determined using the Cohen's d index, are reported as follows: $d < 0.2$ = insignificant effect, $0.2 < d < 0.6$ = small effect, $0.6 < d < 1.2$ = moderate effect, $1.2 < d < 2$ = large effect, $2 < d < 4$ = extremely large effect for the variables of mean force, velocity, power and jump height. Comparisons of SJ_0 condition with the other exercise modalities (SJ_0, CMJ_{wa}, SBJ and $SJ_{elastic}$) are indicated in gray, while comparisons of SBJ condition with CMJ_{wa} and $SJ_{elastic}$ are indicated in black.**

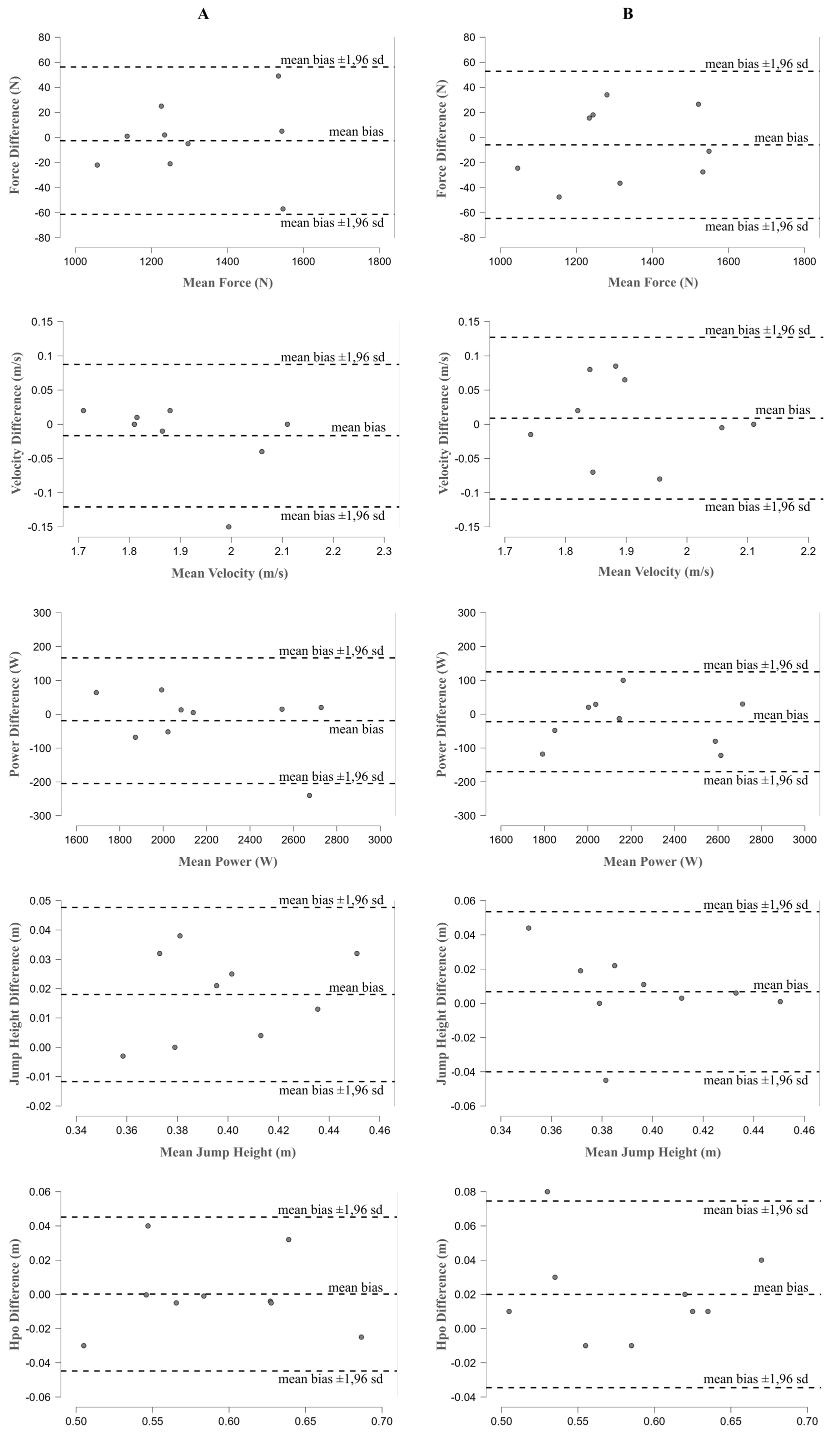

Fig. 4. Bland and Altman plots for the variables of mean force, velocity, power, jump height and hpo for the Swiss Ball Jump exercise modality, both intra-session (A) et inter-session (B). The central horizontal line corresponds to the mean bias, and the upper and lower horizontal lines correspond to the limits of agreement (mean bias ± 1.96 sd).

Table 1. Intra-session reliability for the variables of mean force, velocity, power, jump height and hpo for the Swiss Ball Jump exercise modality.

	Trial n°1	Trial n°2	*ICC*	*CV*(%)
Force (N)	1313 ± 175	1315 ± 173	0.99	1.61
Velocity (m/s)	1.89 ± 0.12	1.90 ± 0.14	0.92	1.98
Power (W)	2185 ± 330	2204 ± 368	0.97	3.05
Jump height (m)	0.41 ± 0.03	0.39 ± 0.03	0.87	2.69
Hpo (m)	0.59 ± 0.06	0.59 ± 0.06	0.93	2.74

Mean ± standard deviation
Abbreviations: *ICC* = intra-class correlation coefficient; *CV* = coefficient of variation

Table 2. Inter-session reliability for the variables of mean force, velocity, power, jump height and hpo for the Swiss Ball Jump exercise modality.

	Session n°1	Session n°2	*ICC*	*CV*(%)
Force (N)	1317 ± 182	1323 ± 177	0.99	1.60
Velocity (m/s)	1.91 ± 0.12	1.90 ± 0.12	0.94	2.24
Power (W)	2200 ± 344	2222 ± 347	0.99	2.41
Jump height (m)	0.40 ± 0.03	0.39 ± 0.04	0.86	4.29
Hpo (m)	0.59 ± 0.06	0.57 ± 0.06	0.85	3.29

Mean ± standard deviation
Abbreviations: *ICC* = intra-class correlation coefficient; *CV* = coefficient of variation

Discussion

To our knowledge, this study is the first to quantify the mechanical outputs of force, velocity, power, jump height and hpo during vertical jumps assisted by a swiss ball. The main result shows that the SBJ exercise modality allows athletes to attain much higher lower limb extension velocity (68.4%11.4%; $ES = 4.2$; $CI = [0.09; 8.28]$) than those observed during an SJ_0, a trend consistent with the velocity values generally reported for SJ in the literature (8,11,17), positioning the SBJ in the velocity part of the force-velocity-power spectrum and confirming its pertinence as an exercise specifically oriented towards stimulating the capacity to produce velocity during jumps.

This study also shows that this new exercise modality, the SBJ, allows athletes to attain significantly higher lower limb extension velocity (22.5%7.40%; $ES = 1.9$; $CI[-0.05; -3.82]$) than those observed during an CM_{wa}, a trend consistent with the velocity values generally reported for CMJ and CM_{wa} in the literature (5,18). These results place the SBJ as a more effective exercise modality than the CMJ performed with or without arm assistance for stimulating the capacity to produce velocity during jumps. This study also shows that the SBJ exercise modality allows athletes to attain slower lower limb extension velocity (-9.19%17.7%; $ES = -1.34$; $CI[-3.01; 0.32]$) compared to those observed during an $SJ_{elastic}$ corresponding to a reduction of 38.3% ± 7.3% of body weight. However, the velocity values obtained using the SBJ (1.97 ± 0.13 m/s) are similar or even higher than those reported for vertical jumps (SJ or CMJ) assisted with negative loads of approximately 10%, 20%, 30%, and 40% of body weight (2,7,19). These results indicate that SBJ is a more or less effective exercise modality than SJ performed with elastic assistance for stimulating the capacity to produce velocity during jumps, depending on the magnitude of the weight reduction applied. We should mention that this study did not compare the SBJ exercise modality with the two other existing exercise modalities designed to stimulate jump velocity, i.e., the horizontal squat jump (HSJ) and the assisted horizontal squat jump (AHSJ), due to the absence of the equipment required for their evaluation. Nevertheless, the velocity values obtained during the SBJ (1.97 ± 0.13 m/s) are higher than those reported for horizontal SJs in a similar population (HSJ: 1.58 ± 0.19 m/s ; AHSJ: 1.83 ± 0.19 m/s) (8), suggesting that the SBJ is a more effective exercise modality than horizontal SJs, assisted or not by an elastic band, for stimulating the capacity to produce velocity during jumps.

Also, this study shows that the SBJ allows athletes to attain higher jump heights (29.3% ± 17.4% ; ES = 0.7 ; CI [-0.11 ; 1.44]) than those observed during a SJ_0, this trend is coherent with the SJ_0 jump height values reported in the literature (20,21). It shows that the SBJ allows athletes to attain largely lower jump heights (-61.9%10.4%; $ES = -5.3$; $CI[-11.1; 0.44]$) than those observed during a $SJ_{elastic}$, a trend consistent with the $SJ_{elastic}$ jump height values reported in the literature (7). However, the jump heights obtained during a SBJ are comparable (0.85%14.0%; $ES = 0.0$; $CI[-0.53; 0.54]$) to those observed during a CM_{wa}, a trend consistent with the jump heights values generally reported for CMJ and CM_{wa} in the literature (5). These results can be explained by the similarity between the two exercise modalities (SBJ and CMJ with arms), because they have common mechanical characteristics, particularly the presence of a countermovement and the arms assistance.

Contrary to the $SJ_{elastic}$ exercise condition, where there is a considerable inter-individual variability in both velocity (2.22 ± 0.38 m/s) and jump height (1.20 ± 0.36 m), probably due to individual differences in the effects of the elastic assistance (corresponding to a reduction of 38.3% ± 7.3% of body weight) and consequently influenced by the participants' body mass (69.6 ± 11.9 kg), the SBJ exercise condition shows a much lower inter-individual variability in both velocity (1.97 ± 0.13 m/s) and jump height (0.41 ± 0.03 m), suggesting that the assistance offered by the swiss ball allows for more homogeneous performance.

It is important to note that this study shows satisfying intra- and inter-session reproducibility. All variables (mean force, velocity, power, jump height and hpo) presented ICC values attesting to an "excellent" relative reliability, and all CVs were lower than 10% which corresponds to an absolute reliability considered "acceptable". Additionally, Bland and

Altman plots show a low mean bias, and values are generally within the 95% limits of agreement. These results suggest that the SBJ is a reliable exercise modality for monitoring mechanical performance (mean force, velocity, power, jump height and hpo) during evaluations, thus allowing the detection of fine and significant variations due to training or experimental interventions.

Practical applications

This study presents an original exercise modality, the SBJ, which offers considerable potential for practical applications in the field and is a useful resource for strength and conditioning coaches.

- The SBJ is a reliable exercise modality for producing high levels of lower limb extension velocity during jumps. It offers an effective additional alternative to the short list of exercise modalities that target this specific ability, such as the CMJ with arm assistance, the SJ or CMJ with elastic assistance, and the horizontal SJs.
- The SBJ is a simple exercise to use. It only requires a 65 centimetre diameter swiss ball, which is a non-expensive equipment and already present in many clubs, facilitating its integration into the field practice. Moreover, the instructions are easy to understand and respect.
- Unpublished internal data suggest that integrating this new exercise modality into an individualized training program based on force-velocity profile, could be effective for correcting a velocity deficit and optimizing vertical jump performance.

Limitations

As the first study on this topic, there are naturally some limitations, which could be investigated in the future research to confirm the results, improve understanding of the subject, and formulate more precise recommendations for using the SBJ.

- We speculate that the size of the swiss ball used (to our knowledge, available on the market with diameters from 45 to 75 centimeters) could influence the countermovement depth, thus modifying the vertical push-off distance and consequently the mechanical performance (mean force, velocity, power and jump height), similarly to what is observed during the SJ and CMJ (22,23).
- In the same way, we think that changing the swiss ball's inflation level could affect its mechanical properties, like the elasticity, the deformation, or the energy return. We think these modifications could then influence the amplitude of the countermovement depth, thus modifying the vertical push-off distance and consequently the mechanical performance (mean force, velocity, power and jump height).

Conflict of interest statement

The authors do not have any conflict of interest or personal relationship with other people or organisations that could inappropriately influence this work

Data availability

The data are made available to all interested researchers upon request *.

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