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Effect of Body Position and Support Surface on the Postural Control Challenge During the Pallof Press Exercise: A Smartphone Accelerometer-Based Study

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Abstract: Although different variations of the Pallof press exercise are commonly performed in sport and fitness settings to increase core stability, the intensity/difficulty of these variations is unknown and therefore it is difficult to control the training load and establish exercise progressions. This study aimed to compare and rank the postural control challenge imposed by five different isometric variations of the Pallof press exercise through a smartphone accelerometer placed on the participants' pelvis and to explore sex differences in the lumbopelvic postural control during the exercise performance. Twelve physically active participants completed two testing sessions in which they performed two sets of five different isometric variations of the Pallof press exercise (changing the body position and/or the support surface: kneeling on a foam pad, feet together standing on the floor, tandem stance on the floor, feet together standing on a hemisphere ball, and tandem stance on a hemisphere ball). After confirming the acceleration data reliability (intraclass correlation coefficients≥ 0.72 and typical errors≤ 17%), a repeated measures ANOVA was carried out to classify the Pallof press variations according to the postural control challenge imposed on the participants and to analyze sex differences on postural control. Significant effects were found for the within-subject factor *exercise variations* but not for the between-subject factor *sex*. Pairwise comparisons showed that the exercise variations performed on the hemisphere ball (feet together standing: 0.55 m/s^2; tandem stance: 0.61 m/s^2) imposed higher postural control demands than those performed on the other surfaces (kneeling on a foam pad: 0.17 m/s^2; feet together standing on the floor: 0.22 m/s^2; tandem stance on the floor: 0.31 m/s^2). In addition, tandem stance on the floor produced higher lumbopelvic accelerations than the Pallof press kneeling variation. In conclusion, the Pallof press performance in standing rather than kneeling (i.e., reducing the base of support and raising the center of gravity and the height of the lateral force applied by the elastic band) and on a hemisphere ball increased the exercise difficulty compared to more stable surfaces. This information could help to modulate the difficulty and establish progressions for this exercise in physically active young males and females.

Keywords: core stabilization; training intensity; load progression; field testing; posturography; trunk control

Introduction

Nowadays, exercise programs aimed at improving core stability (CS) are common elements in fitness, physical education, rehabilitation and amateur and professional sport (Ekstrom et al., 2007; Lago-Fuentes et al., 2018; Oliver et al., 2010; Reed et al., 2012; Watson et al., 2017). However, despite its popularity, there is no clear evidence of the benefits of CS in different contexts, especially in sports performance (Reed et al., 2012; Vera-García et al., 2015). The lack of specificity of both, the exercises and the tests used in the experimental studies, could be highlighted among the different reasons why CS exercises might not have shown benefits for athletes (Barbado, Barbado, et al., 2016; F.J. Vera-Garcia et al., 2019). In this sense, according to the study of Barbado et al. (2016), only those tests that require sport-specific trunk stability demands are suitable for measuring this quality in athletes practicing that sport. Similarly, trunk stability exercises performed by these athletes should challenge the stability in similar conditions to those specific to their sport, which in many cases are far from conventional training.

Generally, conventional CS exercises are performed in quadruped, prone, supine or lateral decubitus positions (Escamilla et al., 2016; Heredia-Elvar et al., 2024; Francisco J. Vera-Garcia et al., 2020b; Francisco J Vera-Garcia et al., 2014). This type of workouts challenge postural control, inducing moderate trunk muscle activations (García-Vaquero et al., 2012; Imai et al., 2010; Moreno-Navarro et al., 2024; Prat-Luri et al., 2023) without exposing the spine to high levels of stress (Kavcic et al., 2004). In addition, they do not need expensive equipment and they are relatively easy for health and sport professionals to monitor. However, this type of workout is not very ecological according to the usual stability needs of sports skills nor for coping with the demands of daily living tasks, which usually happen in more vertical positions (standing, sitting, etc.). In this sense, conventional floor-based CS exercises could be more useful for beginners than for athletes or people with high postural control, who require a more ecological training that uses CS exercises performed in specific positions.

The Pallof press, a transverse plane or trunk rotation exercise that basically consists in keeping the spine and pelvis in a neutral position against the torsion moment generated by a lateral force applied on the trunk through a cable or a rubber/elastic band held by the participant, could be highlighted between the CS exercises performed in standing positions. During the conventional form of this exercise, the participant tries to keep the trunk still while extending and flexing the elbows (against the lateral force), which modifies the lever arm and therefore the torsional moment on the trunk (Mullane et al., 2021). There are different variations of the Pallof press technique depending on the body position (standing, seated, half-kneeling, etc.), on whether the cable/band is held with one or two hands, if the exercise is performed with or without limb movements, etc. (McGill et al., 2009; Mullane et al., 2021). However, although a Pallof press progression for the design of training programs has been proposed by Mullane et al., (2021), there is a lack of objective criteria to assess the intensity of different variations of this exercise and ultimately establish difficulty progressions are lacking.

The main objective of this study was to develop a progression of five isometric variations of the Pallof press exercise performed in different body positions (kneeling, feet together standing, and tandem stance) and on different support surfaces (a foam pad, the floor and a hemisphere ball). Considering the reliability, low cost and ease of use of the accelerometers embedded in smartphones to establish CS exercise progressions based on the postural control challenge imposed on the participants by these exercises (Barbado et al., 2018; Heredia-Elvar et al., 2021, 2024; Vera-Garcia et al., 2020b), this technique was used to assess the difficulty the participants had to perform each Pallof press variation. In addition, sex differences in the lumbopelvic postural control were also analyzed as previous posturographic studies have found higher postural control during CS exercises in females (Vera-Garcia et al., 2020a). Finally, this study explored the acceleration data consistency, since we have no evidence that the smartphone accelerometry has been used before during the execution of this exercise.

Method

Participants

A total of 6 males (age: 30.5 ± 11.0 years; height: 173 ± 0.7 cm; body mass: 77.0 ± 6.7 kg) and 6 females (age: 25.6 ± 3.9 years; height: 165.9 ± 5.7 cm; body mass: 61.9 ± 6.0 kg) participated in this study. The participants were physically active and performed at least 150 min of moderate physical activity or 75 min of vigorous physical activity per week. They did not present any injury or pathology that contraindicated the practice of physical exercise and they had not taken part in any structured and specific core training program in the 6 months prior to this study. They were informed of the risks of this study and filled out a written informed consent according to the Declaration of Helsinki and approved by the Miguel Hernández University Office of Research Ethics (DCD.CJR.230630).

Procedures

The participants completed two testing sessions (of approximately 45-60 min each separated one week apart) in which they performed two sets of five variations of the Pallof press after a 10-minute standardized warming up (Barbado et al., 2018) in each session (1 min rest between variations and 5 min rest between sets). The participants had to maintain the required posture for 15 s and the average acceleration (m/s^2) of the lumbopelvic area was registered using the Coremaker application. For this purpose, an accelerometer integrated in a smartphone (iPhone SE model, MHGQ3QL/A; USA) was placed over the sacrum using an elastic belt. They had two opportunities to complete each variation (if not, it was concluded that they were unable to perform it).

Pallof Press Variations

The participants performed five isometric Pallof press variations in the same order as shown in Figure 1: 1) kneeling on a semi-rigid foam pad (30 x 10 x 5 cm; 80 kg/m^3); 2) with their feet together standing on the floor; 3) tandem stance on the floor; 4) with their feet together standing on a hemisphere ball (turtle model T2; dimensions of 65 cm diameter by 25 cm height); and 5) tandem stance on a hemisphere ball. Although, the Pallof press is usually performed with upper limb movement, in this study it was carried out with the elbows extended to avoid sudden trunk movements and to improve the reliability of the accelerometry data. During the execution of each Pallof press variation, the participant, keeping the arms extended perpendicular to the body at shoulder height, used both hands to hold a handle attached to an elastic band anchored to a pulley machine which facilitated the placement of the elastic band on a horizontal plane (i.e., the elastic band direction had to follow a straight trajectory with respect to the position of the hands). Finally, a digital dynamometer (Gram Lite CR-30; Spain) attached to the elastic band (Figure 2) was used to standardize the resistance of the elastic band according to the participant's body weight. A pilot study was carried out to establish the lateral force generated by the elastic band on the participants according to their body weight. The main results are as follows (body weight: lateral force): 50-60 kg: 4 kg; 60-70 kg: 4.5 kg; 70-80 kg: 5 kg; 80-90 kg: 5.5 kg; >90 kg: 6 kg.

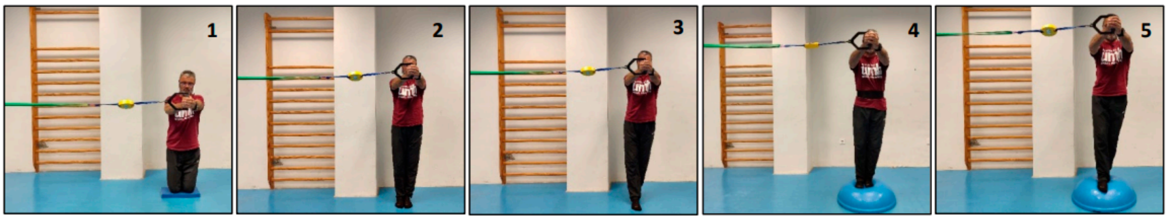

Figure 1. Images of a participant performing the Pallof press variations: 1) kneeling on a foam mat; 2) feet together standing on the floor; 3) tandem standing on the floor; 4) feet together standing on a hemisphere ball; 5) tandem standing on a hemisphere ball.

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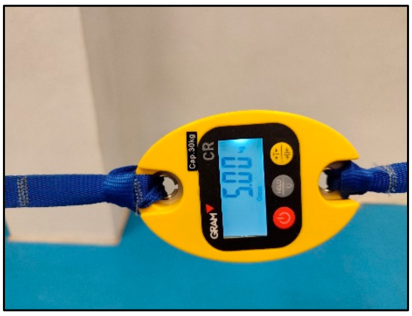


Figure 2. Image of the dynamometer showing 5 kg of lateral force generated by the elastic band on a participant.

Statistical Analysis

Descriptive statistics, including mean (average of the two trials of each session) and standard deviations, were calculated for the pelvic acceleration of each exercise variation of the entire sample. A Kolmogorov-Smirnov test with the Lilliefors correction ($p< .05$) was used to confirm the normal distribution of the pelvic acceleration data. A spreadsheet designed by Hopkins (Hopkins, 2015) was used to analyze test-retest reliability through the typical error (standard deviation of the difference between the two sessions divided by √2) and the intraclass correlation coefficient ($ICC_{3,1}$) with its confidence limits set at 95%. ICC values were interpreted according to the following criteria: excellent (0.90–1.00), good (0.70–0.89), fair (0.50–0.69), and low (<0.50) (Fleiss, 1999). Based on previous reliability data for the involved procedures (Barbado et al., 2018), typical error≤ 20% was considered adequate for the posturographic analysis.

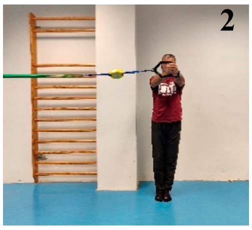
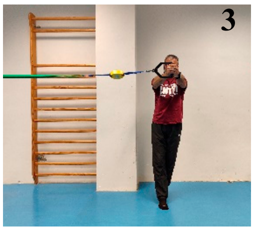
A 2-way mixed analysis of variance (ANOVA) was performed to classify the Pallof press variations according to the postural control challenge imposed on the participant and to analyze sex differences with the data obtained in the second session. The within-subject factor was *exercise variations* (five Pallof press variations), whereas the between-subject factor was *sex* (males and females). All the statistical analyses were performed with the JASP package (version 0.18.1, Netherlands), establishing significance at $p<.05$.

Results

Table 1 shows the descriptive statistics for session 1 and session 2 in which mean pelvic acceleration values ranged from 0.17 to 0.61 m/s^2. Regarding data consistency, the relative reliability was good with ICC≥ 0.72, and the absolute reliability was acceptable, according to previous studies (Barbado et al., 2018), with typical errors≤ 17%. There were no statistical differences between sessions 1 and 2 for the mean acceleration values obtained from each Pallof press variation.

The repeated-measures ANOVA showed significant differences in the within-subject factor *exercise variations* ($F= 65.701$; $p< .001$) but not in the between-subject factor *sex* ($F= 0.579$; $p= .464$). Figure 3 shows the pairwise comparisons in mean pelvic acceleration between the exercise variations and the resulting intensity progression based on the difficulty the participants had to maintain each Pallof press position. The Pallof press variations performed in standing position on the hemisphere ball (feet together standing: 0.55 m/s^2; tandem stance: 0.61 m/s^2) showed higher mean acceleration values than those variations performed in standing position on the floor (feet together standing: 0.22 m/s^2; tandem stance: 0.31 m/s^2) and kneeling on the foam pad (0.17 m/s^2). In addition, tandem stance on the floor produced higher lumbopelvic accelerations than kneeling on the foam pad.

Table 1. Descriptive statistics and absolute and relative reliability.

Variables		Session 1 (mean±SD)	Session 2 (mean±SD)	Change in mean (95% CL)	Typical error (%) (95% CL)	ICC$_{(3,1)}$ (95% CL)
ISOMETRIC PALLOF-PRESS (m/s^2)		0.17±0.05	0.17±0.06	-0.01 (-0.03 - 0.02)	0.03 (17%) (0.02 - 0.05)	0.74 (0.31 - 0.92)
		0.25±0.07	0.22±0.06	-0.04 (-0.07 - -0.01)	0.03 (14%) (0.02 - 0.06)	0.80 (0.42 - 0.94)
		0.29±0.09	0.31±0.10	0.01 (-0.03 - 0.05)	0.04 (15%) (0.03 - 0.07)	0.81 (0.46 - 0.94)
		0.57±0.17	0.55±0.15	0.00 (-0.09 - 0.08)	0.09 (16%) (0.06 - 0.16)	0.72 (0.25 - 0.91)
		0.59±0.12	0.61±0.21	0.07 (-0.03 - 0.17)	0.09 (14%) (0.06 - 0.17)	0.82 (0.32 - 0.95)

SD: standard deviation; CL: confidence limits; ICC: intraclass correlation coefficient. Pallof press variations: 1) kneeling on a foam pad; 2) feet together standing on the floor; 3) tandem stance on the floor; 4) feet together standing on a hemisphere ball; 5) tandem stance on a hemisphere ball.

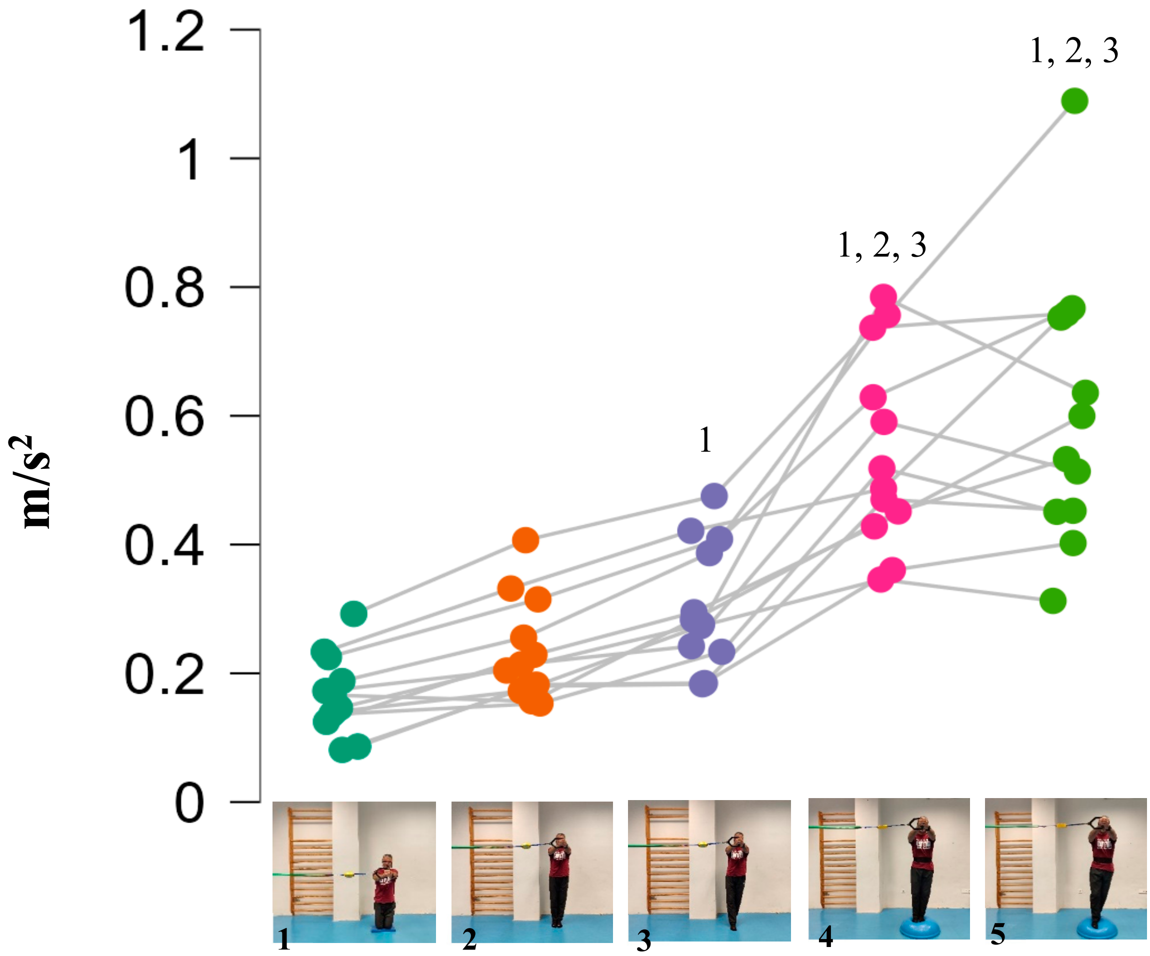


Figure 3. Pallof press progression based on the postural control challenge imposed for each exercise variation on the participants: 1) kneeling on a foam mat; 2) feet together standing on the floor; 3) tandem standing on the floor; 4) feet together standing on a hemisphere ball; 5) tandem standing on a hemisphere ball. [1]Significant differences with kneeling on a foam mat. [2]Significant differences with feet together standing on the floor. [3]Significant differences with tandem standing on the floor.

Discussion

Nowadays, different Pallof press variations are performed in sport and fitness settings varying the body position, using a cable or elastic band grip, carrying out limb movements, changing the support surface, etc. (McGill et al., 2009; Mullane et al., 2021). However, despite the popularity of this exercise, the intensity/difficulty of these Pallof press variations is unknown, and therefore, it is difficult to control the training load and establish exercise progressions. To the best of our knowledge, this is the first study that provides objective data from a smartphone accelerometer that allows to compare and rank the postural control challenge imposed by five different isometric variations of the Pallof press exercise performed in different body positions and on different support surfaces (Figure 3). The main findings were: i) the good data consistency; ii) the absence of sex differences in postural control during the exercise variations; and iii) that the Pallof press performance in standing position rather than kneeling, and on a hemisphere ball compared to more stable surfaces, increased the exercise difficulty.

As previously mentioned, the data consistency was good (ICC≥ 0.72, typical errors≤ 17%) and slightly better than those obtained in previous smartphone accelerometer studies on other CS exercises (Heredia-Elvar et al., 2024; Francisco J. Vera-Garcia et al., 2020b). Regarding the between-sex analysis, males and females did not show significant differences in postural control when performing the Pallof press variations. These results are not in line with previous findings in a posturographic study on conventional floor-based CS exercises (Vera-Garcia et al., 2020b), which found better postural control in females than in males in most exercises (i.e., lower lumbopelvic accelerations during bridging and bird-dog exercises). However, to compare the results of both studies is difficult, since the exercises are performed in different positions (i.e., lying or quadruped positions *vs*. standing or kneeling positions), the level of the postural control is affected by variables that were not controlled in either study (i.e., training experience with these exercises, participants' morphological characteristics, etc.), and the sample size of the current study is small. Therefore, further research is needed to understand the role of sex in the performance of the Pallof press and other CS exercises.

As Figure 3 shows, one of the main findings of the study was that, in general, the standing variations imposed higher postural demands than the kneeling variation. This could be probably caused by: i) the smaller base of support and the higher center of gravity while standing, which reduces the fall angle of the body; and ii) the higher height of the lateral force applied by the elastic band, which increases the tilting moment on the participant's body. On the other hand, despite the lower lateral base of support when the feet were placed in tandem position compared to the feet together position, no significant pelvic acceleration differences were observed between these feet positions in standing, nor in the variations performed on the floor or in those performed on the hemisphere ball. However, as shown in the images presented in figure 1, although in each standing variation (especially the variation on the hemisphere ball) the participants leaned laterally in the opposite direction to the lateral force applied by the elastic band to maintain the position, this strategy was mainly observed during the variations performed with the feet in tandem position (i.e., with lower lateral base of support). Further research is needed to understand the postural and neuromuscular effect of these and other foot positions on the Pallof press execution better. Finally, regarding the comparison between the Pallof press variations performed on the hemisphere ball and those performed on the floor (Figure 3), current results support the use of unstable surfaces (i.e., hemisphere balls, Swiss balls, suspension bands, and others) as a criteria to increase the intensity of the CS exercises (Feldwieser et al., 2012a; Heredia-Elvar et al., 2024; Vera-Garcia et al., 2020a).

The interpretation of the results of this study is limited to physically active people, so further research is needed to establish CS exercise progressions in other populations (athletes with different stability demands, patients with low back pain or balance deficits, etc.). Besides, as stated above, the small sample size is one of the main limitations of this study, as it makes comparison between males and females difficult and it could increase the probability of making a false negative error. Moreover, although the conventional Pallof press execution implies elbow flexion-extension movements, the Pallof press variations analyzed in this study were performed with the elbows held in full extension (i.e., with the largest lever arm). This was done to avoid sudden upper limb movements which could have altered the lumbopelvic acceleration recording and affected the data reliability.

Conclusions and Practical Applications

Based on the current results, the Pallof press performance in standing rather than kneeling, and on a hemisphere ball compared to more stable surfaces, increased the exercise difficulty in physically active young males and females. Overall, this information can be used by clinicians, physical trainers and researchers to modulate the difficulty and establish progressions for the Pallof press exercise. In this sense, standing Pallof press variations seem to be a better option to increase exercise difficulty while performing tasks in more functional positions than kneeling variations (e.g., for both, athletes and people who perform physical activity for health and well-being), as well as to reduce stress on the knees (e.g., in individuals with knee injuries). On the other hand, kneeling positions may be more appropriate to reduce lower limb involvement and exercise difficulty, allowing the increase of the magnitude of the lateral force applied on the participant (i.e., using stiffer elastic bands or increasing the resistance mobilized on cable-pulley machines) and thus the activation of the core muscles. Regarding the use of the hemisphere ball, performing Pallof press variations on this unstable surface represents a significant challenge for many participants, so they seem to be indicated for people with great postural control. In this sense, the great difficulty in maintaining body posture on the hemisphere ball during this exercise could reduce the ability of less experienced participants to focus on the core structures, transforming the Pallof press into a whole-body balance exercise rather than a CS exercise.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets obtained and analyzed for the current research can be provided by the authors of this study.

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