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Can 5-weeks of Hypopressive Exercise Influence Sagittal Lumbo-Pelvic Position in Athletic and Non-Athletic Females?

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ABSTRACT

International Journal of Exercise Science 16(4): 550-562, 2023. Hypopressive exercises (HE) are part of the Low Pressure Fitness training program which is widely used by physical therapists in the rehabilitation of the pelvic floor, abdominal and spinal musculature. The aim of this study was to compare the effects of HE on the sagittal lumbo-pelvic posture in athletic and non-athletic females. It was hypothesized that a 5-week training program of HE could influence lumbo-pelvic position while reducing abdominal circumference and low back pain in athletic and non-athletic females. Twenty normoweight females (mean age = 24.8 (SD 3.5) years; body mass index = 22.4 (SD 1.6) kg/m2) participated in this study. Ten athletic females were rugby players (RG), and 10 females were non-athletic (SG). Participants completed twenty minutes of HE twice weekly for 5 weeks. Before and after the intervention, two-dimension photogrammetry was used to assess lumbar lordosis and pelvic horizontal alignment. A Visual Analog Scale was used to assess low back pain and cirtometry was used to assess abdominal circumferences at umbilical, supra and infra-umbilical levels. An analysis of variance between moments revealed no significant differences in lumbar lordosis and pelvic positioning but showed significant differences for abdominal circumferences between groups. No significant differences between groups were found for other variables. Significant correlations were found between the three different abdominal circumference measurements ($p > 0.05$) but not between lumbar lordosis and abdominal circumferences. These preliminary findings indicate that a 5-week HE intervention displayed non-significant changes in lumbar lordosis, pelvic horizontal alignment, and low back pain but a significant reduction in abdominal circumferences in non-athletic and athletic females.

KEY WORDS: Sagittal alignment, breathing exercise, lumbar lordosis, low back pain, pelvic tilt, abdominal circumference

INTRODUCTION

The normal curvatures of the spine in the sagittal plane (thoracic kyphosis and cervical and lumbar lordosis) are balanced with each other in a normal bipedal posture (1). A variety of intrinsic and extrinsic factors can impact postural abnormalities which may be structural or non-structural. Postural alignment deviations have been associated to alterations in movement patterns or range of motion (15). Further, abnormal lumbopelvic sagittal alignment has been considered a predisposing factor for low back pain (LBP) (12, 30). Subgroups of people with LBP have been shown to display differences in their lumbar alignment (12). In adults, a common non-structural spinal misalignment in the sagittal plane is lordotic posture which is characterized by increased lumbar lordosis (LL) and increased anterior pelvic tilt (1, 15). The different sagittal spinal curves are known to impact the muscle activity of the stabilizing muscles (13).

The body's gravitational line crosses the vertebral curvatures, which are balanced both anteriorly and posteriorly. Deviation from this line results in altered balance, triggering compensatory processes, altering the entire postural kinetic and biomechanical chain (1, 5). The position of the pelvis is maintained by the balanced action of the abdominal, vertebral extensor, and hip muscles. When these muscle groups are dysinergistic, the pelvis tilts forward and the abdominal and pelvic contents press the abdominal wall, which stretches, causing an increase in intra-abdominal pressure, which can cause overload in the lumbar and a proportional angulation in the pelvis to remain as balanced as possible (3, 13).

Therapeutic exercise is a conservative approach for lumbopelvic stabilization and postural alignment. Over the past few years, hypopressive exercise (HE) has emerged as an alternative therapeutic for the treatment of spinal disorders such as scoliosis (9), chronic nonspecific low back pain (6, 7, 41) and for the recovery of deep abdominal and pelvic floor muscles (31, 33). HE has been proposed as a means of lumbo-pelvic training through specific postural adjustments (i.e, spinal alignment and axial spinal lengthening, axis forward) performed in a variety of body positions while slow deep breathing (31, 36). The main part of the session consist of a flow of static poses combined with the breathing maneuver feature of HE named the abdominal vacuum maneuver (11).

Despite the increasing use of HE, only one study has addressed its impact on lumbo-pelvic sagittal alignment in a group of 29 healthy adults (10). Reductions in LL were observed in the HE group compared to control group (10). The impact of HE on trunk alignment on physically active populations remains unknown. A recent study assessed the effects of an 8-week training protocol of HE on female professional basketball players who exhibited a decrease of LBP levels and increased posterior chain kinematics (40). Another 8-week HE training protocol with female rugby players reported an increase in transverse abdominis contractility and a decrease in abdominal circumference (2). In fact, increased transverse abdominis activation with HE has been previously described in adult healthy females (16, 24, 31) supporting the use of HE as an alternative lumbo-pelvic form of training. Previous HE studies on athletes or physically active females (40, 2, 35) were of a non-controlled nature with a non-active group.

To date, there is insufficient evidence regarding the effects of HE on spinal alignment and abdominal circumference in different populations. To further compare the effects of HE on an athletic vs a non-athletic population, the aim of our study was to assess if a HE program could influence sagittal lumbo-pelvic positioning in female athletes compared to a non-athletic matched group. We hypothesized that a 5-week training program of HE could display changes in lumbo-pelvic sagittal position and abdominal circumference independent of athletic background.

METHODS

Participants

This was a before and after intervention study in a group of athletic and non-athletic young adult females. A power analysis conducted with G*POWER 3.1 determined that 20 participants were needed in the present study for a power of 0.80, with an α = 0.05 and an effect size of 1 based on previous data from Álvarez-Sáez et al (2). The intentional sample was composed of twenty adult young females (mean age = 24.8 (SD 3.5) years; body mass index = 22.4 (SD 1.6) kg/m2 who volunteered to participate between November 2019 and March 2020. The non-athletic group (SG) of participants was recruited from the University Methodist Center IPA (Porto Alegre, Brazil) and the Rugby (RG) were recruited from two amateur rugby teams from the city of Porto Alegre (Brazil). After screening, the final sample consisted of 10 rugby players (RG) and 10 non-athletic females (SG). Demographics are presented in Table 1. Inclusion criteria for both groups included a) adult females age range between 18 and 31 years; b) normoweight defined as a BMI between ≥ 18.5 and < 24.9 kg/m2. Inclusion criteria for the SG was defined as a) not participating in any form of exercise, recreational activity, or sport during the previous six months of the study; and b) not engaging in any other form of exercise training during the study period. The inclusion criteria for the RG were to be involved in the sport of rugby for at least the previous six months. This group continued participating in rugby practice during the intervention period. For both groups exclusion criteria included: a) any limitations to perform the abdominal vacuum maneuver such as heart disease and/or pregnancy or high/low blood pressure (17); b) any previous experience training with HE; and c) were undergoing any musculoskeletal rehabilitation program or had any injury limiting their participation in any exercise program.

All participants were informed about the purposes and procedures of the study. Informed consent was obtained from each participant prior to data collection. This study was approved by The Human Research Ethics Committee of the University Center Methodist at Porto Alegre, Brazil (nº 3.453.269), and was conducted in accordance with the Declaration of Helsinki for experiments involving humans gathered at the 64th General Assembly, Fortaleza, Brazil, October 2013, and the relevant Brazilian legislation. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (28).

Table 1. Baseline characteristics of participants
a) Standard deviation; SG: sedentary group; RG: rugby group.

Characteristics	All (*n* = 20) Mean (SD[a])	SG (*n* = 10) Mean (SD)	RG (*n* = 10) Mean (SD)
Age (years)	24.8 (3.5)	24.3 (2.9)	25.3 (4.0)
Body Mass (kg)	58.1 (6.4)	57.3 (7.2)	58.8 (5.7)
Body Height (cm)	160.9 (6.5)	160.5 (5.9)	161.2 (7.4)
Body Mass Index (kg/cm²)	22.4 (1.6)	22.1 (1.9)	22.5 (1.3)

Protocol

Measurements were carried out individually in the laboratory of the Integrated Clinics of the University Method Center IPA (Porto Alegre, Brazil) with controlled environmental temperature. Pre and post measurements were performed by the same evaluator (L.M) who was experienced with photogrammetry assessments. All participants were evaluated the week before and week after the 5-week intervention protocol. Primary outcome measures were lumbo-pelvic position analysis and secondary outcomes were anthropometric measures and LBP levels.

Two-dimensional photogrammetry was used for the assessment of sagittal lumbo-pelvic position. Photogrammetry is a valid, noninvasive, and accurate method for postural analysis of static posture (18, 21). Photogrammetry has been reported to have a good to excellent interrater reliability (25, 37) and is a useful tool in determining interventional effects in clinical practice or in research (8).

We followed the photogrammetry protocol described by Iunes et al. (25). The subjects were positioned standing upright, looking straight ahead with the upper limbs beside the body and in barefoot conditions. They were instructed to wear a swimsuit. With the help of a double-sided tape, Styrofoam spheres with a diameter of 1 cm were fixed on the posterior-inferior iliac spines and anterior-superior iliac spines. Cylindrical rods of 3 cm were fixed on the spinous processes of 7th thoracic vertebrae (T7), 12th thoracic vertebrae (T12) and 5th lumbar vertebrae (L5) for a precise visualization of anatomical landmarks. Photographs were taken in a right lateral view (sagittal plane) using a digital camera (Nikon®, model D500 18-55 mm) with a fixed focal lens, positioned parallel to the floor on a level tripod Targus (model 50 inch) with 1m of height and 2.4 m away from the participants (Figure 1). Photographic records were analyzed using the Postural Evaluation software (SAPO) which is one of the most frequently used software for postural assessment due to its reliability, and ease of use (20, 38). Sagittal postural assessment included angle of LL which refers to the inward curvature of the lumbar spine and angle of pelvic horizontal alignment (PHA) which is determined by the spatial orientation of the pelvis. Forward movement of the pelvis rotation around the axis of the femoral head was defined as anteversion (< PHA angle) and backwards movement as retroversion (> PHA angle).

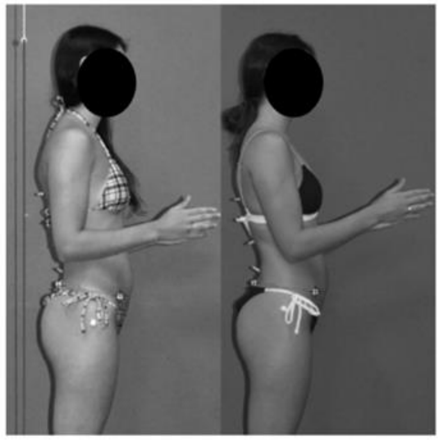

Figure 1. Lumbo-pelvic angles assessed pre and post intervention.

Before carrying out any physical intervention, anthropometric measures were assessed. Height (cm) was measured using a professional stadiometer fixed to the wall (Balmak EST-221 Sanny®, Brazil), and weight (kg) was determined (Balmak scale, model ActLife) by the same trained evaluator. Subsequently, calculation of BMI (kg/m2) was obtained. Measurement of abdominal circumference was performed at three different anatomical sites (midway, umbilical, and infra-umbilical level). Due to differences documented in the absolute values of abdominal circumference measurements across adults and to correlate these different measurements we choose three different anatomic locations (29). All measurements were performed at the end of a normal expiration with a flexible nonelastic WISO anthropometric tape to the nearest 0.1 cm, as recommended by the World Health Organization (43). First anatomic site was located midway between the lowest rib and the superior border of the iliac crest (MC). Second site was measured at umbilicus level (UC) and third site was measured 2.5 cm below the umbilical level (IC). LBP intensity was performed using visual analog scale (VAS) through a 10 cm horizontal line, where the left end of the line indicates absence of pain and at the right end, the greatest pain ever experienced. VAS is a valid, reliable pain-rating scale appropriate for clinical practice (44).

The intervention program was carried on by a physiotherapist certified in HE by the Low Pressure Fitness training school (K.W.) Both groups performed the same intervention protocol and were instructed in how to perform the postures and breathing following the guidelines described in Rial & Pinsach (36). Participants were given cues for postural alignment such as "keep pelvis neutral", "stand tall and lengthen spine" and "widen and open chest". All six poses followed the postural adjustments of: 1) spine elongation with neutral pelvis while sitting; 2) ankle dorsiflexion; 3) slight knee flexion; 4) shoulder girdle muscle activation; 5) axis forward. Each pose was repeated three times. Each repetition was performed with three slow deep breaths followed by an abdominal vacuum maneuver held between a minimum of 6 seconds and a maximum of 25 seconds. The cues given were "expand the rib-cage while holding your breath", "inhale deeply through the nose" and exhale slowly through the mouth". Three breathing cycles and associated breath-holds were considered one completed repetition. The total duration of the exercise intervention was of 20 minutes practiced twice per week. Figure 2 shows the poses practiced in the intervention protocol and their sequential order of practice (pose A to F and pose variations (pose variations 1 to 4).

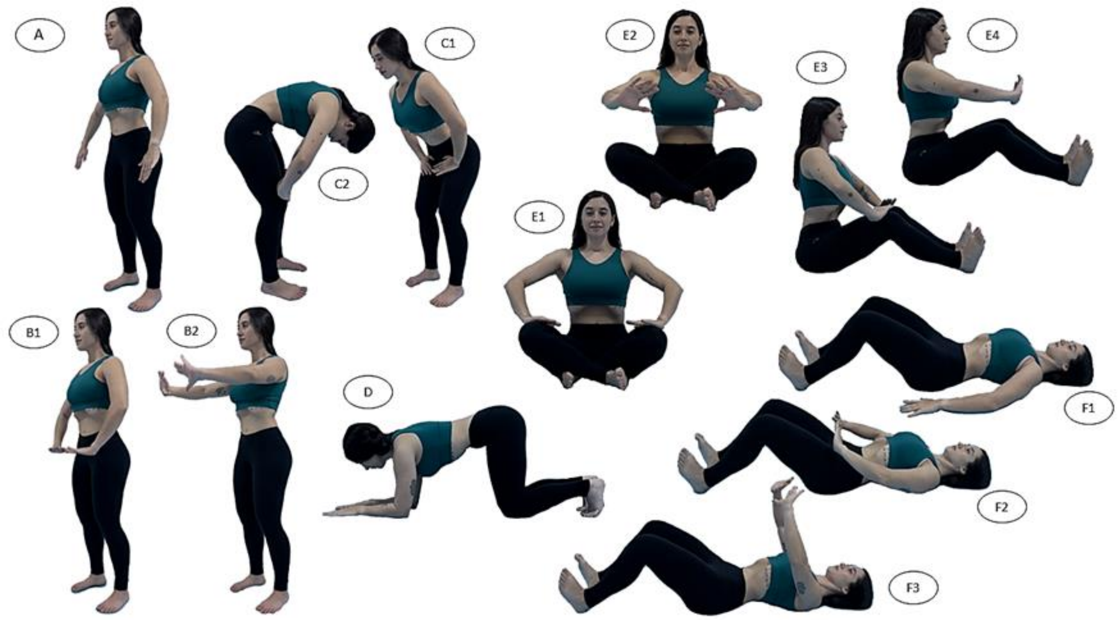

Figure 2. LPF poses performed during the intervention protocol.

Statistical Analysis
A blinded specialist in statistics (not responsible for the intervention or data collection) analyzed the data. All data are reported as mean and standard deviation (SD). For the descriptive analysis the statistical package Statistical Package for the Social Sciences (SPSS), version 25.0 was used. Data distribution was analyzed by the Shapiro-Wilk test. To test differences in groups (SG or RG) a T-test for independent samples for normal distribution variables and Mann-Whitney for non-normal distribution variables was used. Pearson's correlation coefficient was used for normal distribution variables and Spearman's for non-normal distribution variables. The effect size (ES) reported as Cohen's d was calculated to determine the magnitude of the differences between testing moments. Cohen's d values were categorized as "trivial" (< 0.50), "small" (d = 0.50-1.25), "moderate" (d = 1.25-1.9) and large (> 2.0) according to Rhea (34). The level of statistical significance was established as $p < 0.05$ and IC was considered at 95%.

RESULTS

All participants completed the intervention and study related outcome measurements. No adverse events occurred nor were dropouts reported. Sample characteristics are summarized in Table 1. The before and after results for all outcomes in both groups are presented in Table 2. Table 3 presents between group results.

All participants displayed PHA imbalance before the intervention. PHA was found to change in 40% of all participants where 25% (n = 5) changed pelvic position from retroversion to anteversion and 15% (*n* = 3) from anteversion to retroversion. The other 60% (*n* = 12) of participants remained with pelvic horizontal imbalance. LL and PHA degrees did not change significantly between moments for both groups nor between groups.

Abdominal circumference at the three different anatomical locations reduced significantly after the intervention for both groups. However, no differences between groups were noted for abdominal circumference. Body weight displayed no differences significant changes after the intervention protocol for both groups. Also, no differences between groups were noted for abdominal circumferences for all measurement sites. Correlation analysis for abdominal circumference measurements between moments and three different sites revealed high correlations between MC and UC (R2 = 0.723); MC and IC (R2 = 0.731); UC and IC (R2 = 0.895). After the intervention, also high correlations were found between MC and UC (R2 = 0.692); WC and IC (R2 = 0.729); UC and IC (R2 = 0.889). The correlation analysis between LL degrees before the program revealed non-significant correlations for MC (R2 = 0.113), IC (R2 = 0.011) and UC (R2 = -0.009) (p.0 / 05). Similarly, no associations were described after the program between LL and the abdominal circumferences MC (R2 = 0.088), IC (R2 = 0.110) and UC (R2 = -0.089). LBP was only noted by 35% of the participants. Of those with LBP, no significant reductions were noted between moments nor differences between groups.

Table 2. Summary of comparison between moments for all outcome measures.

Outcome Measures	SG (*n* = 10) Pre-test Mean (SD)	SG Post-test Mean (SD)	SG Dif	SG *p*	SG *d*	RG (*n* = 10) Pre-test Mean (SD)	RG Post-test Mean (SD)	RG Dif	RG *p*	RG *d*
LL (degrees)	12.4 (1.9)	13.2 (1.9)	-0.85	0.131	-0.47	13.9 (2.8)	13.5 (1.7)	0.47	0.561	0.17
PHA (degrees)	1.9 (7.0)	1.7 (6.8)	0.18	0.875	0.02	0.0 (4.3)	2.2 (5.5)	-2.2	0.134	-0.44
MC (cm)	70.1 (4.4)	68 (4.2)	-2.1	0.005*	0.48	69 (3.8)	67.7 (3.4)	-1.35	0.018*	0.36
UC (cm)	78 (5.6)	75.4 (5.8)	-2.52	0.008*	0.45	75.3 (3.4)	73.3 (3.2)	-1.93	0.005*	0.60
IC (cm)	82.5 (6.1)	80.9 (5.8)	-1.6	0.017*	0.26	80 (3.6)	78.7 (3.2)	-1.27	0.017*	0.38
Body Weight (kg)	57.3 (7.2)	57.5 (6.9)	-0.2	0.932	-0.02	58.8 (5.7)	58.7 (5.5)	0.1	0.984	0.017
LBP #	5.6 (1.9)	3.7 (2.7)	-1.9	0.109	0.81	2.8 (1.8)	2.0 (2.2)	-0.8	0.465	0.39

**p* ≤ 0.05; SD: standard deviation; SG: sedentary group; RG: rugby group; LL: lumbar lordosis; PHA: pelvic horizontal alignment; MC: midway circumference; UC: umbilical circumference; IC: infra-umbilical circumference; LBP: low back pain; Wilcoxon test; # LBP SG (*n* = 3) RG (*n* = 4), *d*: Cohen's *d*

DISCUSSION

This study aimed to analyze lumbo-pelvic position after a short-term HE program in a group of rugby players and sedentary females. Contrary to our initial hypothesis, findings revealed that 10 sessions of HE did not produce significant changes in LL or pelvic position. However, a short-term program was able to reduce abdominal circumference in both groups for all measurement sites. No differences between groups were found in other analyzed variables.

Table 3. Summary of comparison between athletic vs non-athletic group for all outcome measures.

Outcome Measures	Pre-test SG Mean (SD)	Pre-test RG Mean (SD)	Dif	*p*	Post-test SG Mean (SD)	Post-test RG Mean (SD)	Dif	*p*
LL (degrees)	12.4 (1.9)	13.9 (2.8)	1.5	0.15	13.2 (1.9)	13.5 (1.7)	-0.29	0.74
PT (degrees)[1]	1.9 (7.0)	0.0 (4.3)	-1.9	0.47	1.7 (6.8)	2.2 (5.5)	-0.45	0.87
MC (cm)	70.1 (4.4)	69 (3.8)	-1.1	0.56	68 (4.2)	67.7 (3.4)	-0.35	0.84
UC (cm)	78 (5.6)	75.3 (3.4)	-2.7	0.21	75.4 (5.8)	73.3 (3.2)	-2.11	0.33
IC (cm)	82.5 (6.1)	80 (3.6)	-2.45	0.29	80.9 (5.8)	78.7 (3.2)	-2.12	0.33
Body Weight (kg)	57.3 (7.2)	58.8 (5.7)	-1.5	0.61	57.5 (6.9)	58.7 (5.5)	-1.2	0.69
LBP#	5.6 (1.9)	2.8 (1.8)	-2.8	0.92	3.7 (2.7)	2.0 (2.2)	-1.7	0.88

*$p \leq 0.05$; SD: standard deviation; SG: sedentary group; RG: rugby group; LL: lumbar lordosis; PHA: pelvic horizontal alignment; MC: midway circumference; UC: umbilical circumference; IC: infra-umbilical circumference; LBP: low back pain; Independent T-Student Test [1]; Mann-Whitney Test; # LBP SG (n = 3) RG (n = 4).

To the best of our knowledge, this is the first study to assess static sagittal LL and PHA in an athletic group of young females. The non-clinical features of this population who displayed no spinal disorders nor high levels of LBP could have influenced the results. Previously, RCT with 8-week training protocols of HE described improvements in postural control (31), scoliosis degrees (9), LBP intensity and disability (41) and lumbar mobility (6, 7). The proposed short-term protocol and short session duration could have also influenced the outcomes obtained in our study. In a randomized group of young females, after 10 one-hour HE sessions, decreased LL values compared to the control group were described (10). In contrast to this study, our intervention proposed 10 twenty minutes sessions rather than a one complete hour session to assess if a shorter program could obtain similar results than Caufriez et al (10). Previous interventions with HE in athletic groups proposed HE of 30 min (40) and 20 min (35). A six month RCT on the Pilates method in adult females, found improved sagittal alignment of the pelvis compared to the control group (14). In this RCT, one hour Pilates sessions were practiced over a period of 6 months (14).

Elabd and Elabd (19) found significant associations between LBP intensity and spinopelvic sagittal alignment measured via radiographs. In our study 30% and 40% indicated some mild to moderate levels of LBP. Although there was a trend of decreased LBP this was not significant after the intervention. These results contrast with the decline in LBP intensity described in previous HE studies in female basketball players (40) and in chronic LBP patients (6, 7, 41). In our study there were no significant differences between the athletic and non-athletic group in LBP or lumbo-pelvic alignment. Similar results were yielded in a recent study who described no differences in trunk alignment parameters in the sagittal planes between active participants, with and without LBP, regardless of their level of physical activity (32).

Despite not finding statistically significant differences in lumbar and pelvic angles, a change in pelvic PHA in 40% of all participants was observed. This could be partly explained by the influence of HE on breathing mechanics such as increased rib-cage excursion (40) and diaphragm muscle thickness (41). Postural control and breathing share an interdependent relationship where postural imbalances are associated with changes in diaphragm mobility (22). The diaphragm is fascially connected the trunk musculature and fascia transversalis. Of interest is also the anatomic intersection of the costal section of the diaphragm with the transversus abdominis muscle and its main pillars in the lumbar section to lumbar (i.e, L2, L3) and thoracic vertebraes (i.e, T11, T12). We hypothesize that increased muscle activity of the deep trunk musculature including that of the thoracic diaphragm could have influenced the preliminary pelvic changes in our sample. Indeed, the position of the pelvis is directly related to spine positioning and is responsible for modulating trunk muscle activity (23). In this sense, a study on healthy adults revealed sagittal plane postural changes and breathing amplitude after an exercise program targeting the deep stabilizing muscles (39).

Álvarez-Sáez et al. (2) identified a significant improvement in the contraction pattern of the transverse abdominis and reduction of abdominal circumference in female rugby players without significant changes in trunk muscle and fat mass measured through electrical bioimpedance after 6-weeks of HE. In our study, similar results were noted in all abdominal circumference measurements regardless of the groups athletic activity. It is plausible that the observed abdominal circumferences reduction rates in our study and the report from Álvarez-Sáez et al. (2) could be due to an increased deep trunk muscle activation from the transverse abdominis or diaphragm muscles. Previous RCTs on healthy adult females demonstrated increased transverse abdominal activation after an 8-week protocol compared to a control group in adult females (31). One of the main functions of the transverse abdominis muscle it is to provide lumbo-pelvic stability (23). Rial et al. (35) assessed the immediate effects of one 20-minute sessions of HE in physically active young adults where a decrease of abdominal circumference as well as an increase of posterior chain kinematics was found. Similarly, Teijido et al. (40) also demonstrated back chain kinematics mobility with a HE program in an athletic population. As the hamstring muscles originate in the ischial tuberosity of the hipbone, they could influence pelvis position when elongated, consequently affecting the ascending and descending, lumbar and knee segments. Thus, the preliminary changes presented in the angles of the lumbar and pelvis could be related to the increase in the extensibility of the isquiosural and lumbar muscles observed in previous studies (40, 35). Of note, Araújo et al. presented low to moderate correlation between the pelvis, thoracic and lumbar regions related to hamstring flexibility, reinforcing the existence of a relationship between body posture, flexibility, and mobility (3).

Central obesity and higher obesity have been noted to be potential determinants of non-neutral posture among adults from the general population (3). Our sample consisted of young females with BMI in normal ranges (< 25 kg/m2) and abdominal circumferences below cut off points for women (< 80 cm) as suggested by the World Health Organization (WHO) (43). Both groups, regardless of physical activity levels, demonstrated a reduction in abdominal circumferences at three different locations without changes in BMI or body weight. Previous HE studies found similar results in mid-way abdominal circumference in female rugby players (2) and post-partum females (33). However, we added umbilical and infra-umbilical abdominal circumference measurements which revealed high correlations between the three site locations before and after the intervention. Of interest, no association was found between LL and the abdominal circumferences before and after the intervention. There is still no universal definition of abdominal site measurements. Different international guidelines (i.e., WHO, NIH) recommend different anatomic locations (43, c27). Agarwal et al. (4) found that phase of respiration, posture and time since last meal were all factors influencing waist circumference measurements. Wang et al. (42) compared abdominal circumferences at four different common abdominal locations and found all sites to be highly reproducible.

This study has several limitations. The sample size was small, and we did not include a control group and therefore the results should be interpreted with caution. We did not include the gold standard method for assessing body posture which is X-Ray analysis or assessing body composition which is Dual-Energy X-ray Absorptiometry (DXA). However, two-dimensional photogrammetry and body weight added to abdominal circumferences are considered valid and reliable assessment tools (18). Future studies should assess longer-term postural alignment effects of HE in males and females with spinal disorders and chronic LBP.

Findings from the present study reveal that across all three sites of anatomical abdominal circumference measurement (midway, umbilical, and infra-umbilical) significant reductions were noted for athletic and non-athletic females after 5 weeks of HE. Abdominal circumference anatomical site measurements and changes displayed in healthy normoweight young females are correlated with each other. Our preliminary findings indicate that a 5-week HE intervention displayed non-significant changes in lumbar lordosis, pelvic horizontal alignment, and LBP. These results could aid in the understanding of HE as a means of therapeutic exercise for non-structural spinal misalignments as well as for anthropometric changes at abdominal levels.

REFERENCES

1. Abelin-Genevois K. Sagittal balance of the spine. Orthop Traumatol Surg & Res 107(1S): 102769, 2021.

2. Álvarez Sáez MM, Rial Rebullido T, Chulvi Medrano I, García Soidán JL, Cortell Tormo JM. ¿Puede un programa de ocho semanas basado en técnicas hipopresivas producir cambios en la función del suelo pélvico y composición corporal de jugadoras de rugby? [Can an eight-week program based on the hypopressive technique produce changes in pelvic floor]. Retos 30: 26–29, 2016.

3. Araújo F, Lucas R, Alegrete N, Azevedo A, Barros H. Individual and contextual characteristics as determinants of sagittal standing posture: A population-based study of adults. Spine J 14(10): 2373–2383, 2014.

4. Agarwal SK, Misra A, Aggarwal P, Bardia A, Goel R, Vikram NK, Wasir JS, Hussain N, Ramachandran K, Pandey RM. Waist circumference measurement by site, posture, respiratory phase, and meal time: Implications for methodology. Obesity (Silver Spring) 17(5): 1056–1061, 2009.

5. Baroni BM, Bruscatto CA, Rech RR, Trentin L, Brum LR. Prevalência de alterações posturais em praticantes de musculação. Fisioter Mov 23(1): 129–139, 2010.

6. Bellido-Fernández L, Jiménez-Rejano JJ, Chillón-Martínez R, Lorenzo-Muñoz A, Pinero-Pinto E, Rebollo-Salas M. Clinical relevance of massage therapy and abdominal hypopressive gymnastics on chronic nonspecific low back pain: A randomized controlled trial. Disabili Rehabil 44(16): 4233–4240, 2022.

7. Bellido-Fernández L, Jiménez-Rejano JJ, Chillón-Martínez R, Gómez-Benítez MA, De-La-Casa-Almeida M, Rebollo-Salas M. Effectiveness of massage therapy and abdominal hypopressive gymnastics in nonspecific chronic low back pain: A randomized controlled pilot study. Evid-based Complement Altern Med 2018: 3684194, 2018.

8. Candotti CT, Gelain GM, Antoniolli A, Araújo LM, Vieira A, Loss JF. Repeatability and reproducibility of postural variables by photogrammetry. J Manipulative Physiol Ther 42(5): 372–378, 2019.

9. Caufriez M, Fernández-Domínguez JC, Brynhildsvoll N. Estudio preliminar sobre la acción de la gimnasia hipopresiva en el tratamiento de la escoliosis idiopática [Preliminary study on the action of hypopressive gymnastics in the treatment of idiopathic scoliosis]. Enferm Clin 21(6): 354–358, 2011.

10. Caufriez M, Fernández JC, Fanzel R, Snoeck T. Efectos de un programa de entrenamiento estructurado de gimnasia abdominal hipopresiva sobre la estática vertebral cervical y dorsolumbar. [Effects of a program of constructed training in hypopressive gymnastic on the vertebral cervical and dorsolumbar statics]. Fisioterapia 28(4): 205–216, 2006.

11. Chulvi-Medrano I, Rebullido TR, Gómez-Tomás C, Faigenbaum AD. Feasibility and preliminary efficacy of a hypopressive exercise program on postmenopausal cancer survivors: A pilot study. J Bodywork Mov Ther 24(4): 484–489, 2020.

12. Chun SW, Lim CY, Kim K, Hwang J, Chung SG. The relationships between low back pain and lumbar lordosis: A systematic review and meta-analysis. Spine J 17(8): 1180-1191, 2017.

13. Claus AP, Hides JA, Moseley GL, Hodges PW. Different ways to balance the spine: Subtle changes in sagittal spinal curves affect regional muscle activity. Spine J 34(6): E208–E214, 2009.

14. Cruz-Ferreira A, Fernandes J, Kuo YL, Bernardo LM, Fernandes O, Laranjo L, Silva A. Does pilates-based exercise improve postural alignment in adult women? Women Health 53(6): 597–611, 2013.

15. Czaprowski D, Stoliński Ł, Tyrakowski M, Kozinoga M, Kotwicki T. Non-structural misalignments of body posture in the sagittal plane. Scoliosis Spinal Disord 5(13): 6, 2018.

16. Da Cuña-Carrera I, Alonso-Calvete A, Soto-González M, Lantarón-Caeiro EM. How do the abdominal muscles change during hypopressive exercise? Medicina (Kaunas) 57(7): 702, 2021.

17. De Lucena E, Teixeira L, Mendes CL, Castaño L, Rebullido TR, Uchida MC. Hypopressive exercise in normotensive young women: A case series. J Bodywork Mov Ther 25: 94–99, 2021.

18. Dunk NM, Lalonde J, Callaghan JP. Implications for the use of postural analysis as a clinical diagnostic tool: Reliability of quantifying upright standing spinal postures from photographic images. J Manipulative Physiol Ther 28(6): 386–392, 2005.

19. Elabd AM, Elabd OM. Relationships between forward head posture and lumbopelvic sagittal alignment in older adults with chronic low back pain. J Bodywork Mov Ther 28: 150–156, 2021.

20. Ferreira EA, Duarte M, Maldonado EP, Burke TN, Marques AP. Postural assessment software (PAS/SAPO): Validation and reliability. Clinics (Sao Paulo) 65(7): 675–681, 2010.

21. Furlanetto TS, Sedrez JA, Candotti CT, Loss JF. Photogrammetry as a tool for the postural evaluation of the spine: A systematic review. World J Orthop 7(2): 136–148, 2016.

22. Gonçalves MA, Leal BE, Viegas GC, Lúcio MN, Mazo GZ, Paulin E. Relação entre a mobilidade diafragmática e as curvaturas da coluna vertebral em pacientes com doença pulmonar obstrutiva crônica. Fisioter Pesqui 24(3): 245-252, 2017.

23. Hides J, Wilson S, Stanton W, McMahon S, Keto H, McMahon K, Bryant M, Richardson C. An MRI investigation into the function of the transversus abdominis muscle during "drawing-in" of the abdominal wall. Spine 31(6): E175–E178, 2006.

24. Ithamar L, de Moura Filho AG, Benedetti Rodrigues MA, Duque Cortez KC, Machado VG, de Paiva Lima C, Moretti E, Lemos A. Abdominal and pelvic floor electromyographic analysis during abdominal hypopressive gymnastics. J Bodywork Mov Ther 22(1): 159–165, 2018.

25. Iunes DH, Castro FA, Salgado HS, Moura IC, Oliveira AS, Bevilaqua-Grossi D. Confiabilidade intra e interexaminadores e repetibilidade da avaliação postural pela fotogrametria. Rev Bras Fisioter 9(3): 327-334, 2005.

26. Le Huec JC, Thompson W, Mohsinaly Y, Barrey C, Faundez A. Sagittal balance of the spine. Eur Spine J 28(9): 1889–1905, 2019.

27. National Institute of Health; National Heart, Lung, and Blood Institute. Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. North American Association for the Study of Obesity. The practical guide: Identification, evaluation, and treatment of overweight and obesity in adults. NIH: Bethesda, MD, 2000

28. Navalta JW, Stone WJ, Lyons TS. Ethical Issues Relating to Scientific Discovery in Exercise Science. Int J of Exerc Sci 12(1): 1-8, 2019.

29. Mason C, Katzmarzyk PT. Effect of the site of measurement of waist circumference on the prevalence of the metabolic syndrome. Am J Cardiol 103(12): 1716–1720, 2009.

30. Mitchell T, O'Sullivan PB, Burnett AF, Straker L, Smith A. Regional differences in lumbar spinal posture and the influence of low back pain. BMC Musculoskelet Disord 9: 152, 2008.

31. Moreno-Muñoz M, Hita-Contreras F, Estudillo-Martínez MD, Aibar-Almazán A, Castellote-Caballero Y, Bergamin M, Gobbo S, Cruz-Díaz D. The effects of abdominal hypopressive training on postural control and deep trunk muscle activation: A randomized controlled trial. Int J Environ Res Public Health 18(5): 2741, 2021.

32. Plandowska M, Kędra A, Kędra P, Czaprowski D. Trunk alignment in physically active young males with low back pain. J Clin Med 11(14): 4206, 2022.

33. Ramírez-Jiménez M, Alburquerque-Sendín F, Garrido-Castro JL, Rodrigues-de-Souza D. Effects of hypopressive exercises on post-partum abdominal diastasis, trunk circumference, and mechanical properties of abdominopelvic tissues: A case series. Physiother Theory Pract: 1–12, 2021.

34. Rhea M. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res 18(4): 918-920, 2004.

35. Rial TR, Sousa L, García E, Pinsach P. Efectos inmediatos de una sesión de ejercicios hipopresivos en diferentes parámetros corporales. [Immediate effects of a hypopressive exercise session on different body parameters]. Cuestiones de fisioterapia: Revista universitaria de información e investigación en Fisioterapia 43(1): 13–21, 2014.

36. Rial TR, Pinsach P. Low Pressure Fitness Level 1 Practical Manual. International Hypopressive & Physical Therapy Institute, Vigo, 2017.

37. Ruivo RM, Pezarat-Correia P, Carita AI. Intrarater and interrater reliability of photographic measurement of upper-body standing posture of adolescents. J Manipulative Physiol Ther 38(1): 74–80, 2015.

38. Souza JA, Pasinato F, Basso D, Corrêa ECR, Silva AMT. Biofotogrametria confiabilidade das medidas do protocolo do software para avaliação postural (SAPO). Rev Bras de Cineantropometria e Desempenho Hum 13(4): 299–305, 2011.

39. Szczygieł E, Blaut J, Zielonka-Pycka K, Tomaszewski K, Golec J, Czechowska D, Masłoń A, Golec E. The impact of deep muscle training on the quality of posture and breathing. J Mot Behav 50(2): 219–227, 2018.

40. Teijido SL, Rial-Rebullido T, Gómez-Tomás C, Alonso-Aubin DA, Chulvi-Medrano I. Effects of hypopressive exercise on posterior back chain kinematics and pulmonary function in professional female basketball players. J Sport Rehabil 31(3): 305–312, 2022.

41. Vicente-Campos D, Sanchez-Jorge S, Terrón-Manrique P, Guisard M, Collin M, Castaño B, Rodríguez-Sanz D, Becerro-de-Bengoa-Vallejo R, Chicharro JL, Calvo-Lobo C. The main role of diaphragm muscle as a mechanism of hypopressive abdominal gymnastics to improve non-specific chronic low back pain: A randomized controlled trial. J Clin Med 10(21): 4983, 2021.

42. Wang J, Thornton JC, Bari S, Williamson B, Gallagher D, Heymsfield SB, Horlick M, Kotler D, Laferrère B, Mayer L, Pi-Sunyer FX, Pierson RN. Comparisons of waist circumferences measured at 4 sites. Am J Clin Nutr 77(2): 379–384, 2003.

43. World Health Organization (WHO). Physical status: The use and interpretation of anthropometry. Report of a WHO expert committee. World Health Organ Tech Rep Ser 854: 1–452, 1995.

44. Williamson A, Hoggart B. Pain: A review of three commonly used pain rating scales. J of Clin Nurs 14(7): 798–804, 2005.