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Acute effect of single-session physio-ball wall squat training on knee active reposition sense and isokinetic parameters in sedentary female collegiate students: an experimental study

original paper
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ABSTRACT
Purpose. The current study aimed to examine the acute effect of physioball wall squat training on knee joint active reposition senses and isokinetic parameters of knee flexion and extension in sedentary collegiate female students.
Methods. An experimental study was conducted with sixty sedentary female college students aged between 18 to 25 who were divided into two groups. The experimental group of 30 participants performed Swiss ball wall squats, spanning three sets of 12 repetitions each, with 30-second rest intervals between sets. The control group of 30 participants stood with a Swiss ball positioned behind their backs, replicating the same parameters as the experimental group but without squatting. The isokinetic 4 Pro device measured active knee joint repositioning senses and isokinetic parameters of knee flexion and extension.
Results. The findings revealed notable improvements in active knee repositioning senses and all isokinetic parameters of knee flexion and extension ($p < 0.05$) in the experimental group post-training when compared to the control group. There were also significant differences detected between pre- and post-Swiss ball training intervention in the experimental group for all variables ($p < 0.05$).
Conclusions. These results suggest that Swiss ball wall squat training could enhance knee joint position senses and isokinetic parameters, potentially reducing knee injuries in sedentary individuals.
Key words: exercise ball, kinesthesis, knee joint, muscle strength, females, sedentary behaviour

Introduction

Unstable surface training is known to enhance neuromuscular adaptations, reduce injury rates, and improve coordination and balance, as opposed to focusing solely on muscle strength [1]. It often incorporates various devices, including balance boards [2], foam rollers, trampolines, physioballs [3], and whole-body vibration devices on unstable surfaces [4]. This form of training primarily aims to minimize the contact area with the ground, creating an unstable condition. The resulting physiological changes can induce more effective proprioceptive responses, enhancing balance skills, and active protection mechanisms [5].

For almost 40 years, the physioball, sometimes known as the Swiss ball, has been utilized in physical therapy for orthopaedic rehabilitation and neurodevelopmental treatment [6]. These physioballs have been

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found to be useful in various areas, including muscle strength training, postural balance training, sports rehabilitation, physical education, special education, physical fitness, and flexibility training [7, 8]. Thanks to their dynamic nature, physioball exercises can enhance balance, body awareness, flexibility, strength, and posture, as well as improve equilibrium and proprioception [9].

Proprioception is a form of sensory input that influences joint position during daily activities [10]. It can also be seen as signals transmitted from the body's extremities that help maintain joint position and stability, postural balance, and other sensory perceptions [11]. Moreover, proprioception, which is the body's ability to perceive its own position in space, helps regulate posture and perform accurate movements while performing actions such as walking, running, or jumping, particularly within the knee joint [12].

Knee joint proprioception directly affects the ability to sense the position of the knee joint by providing feedback about joint angles and movements, which is crucial for balance and coordination [13]. Understanding the impact of altered proprioception can aid in developing effective rehabilitation strategies. Nevertheless, there are no standardized methods or tools for evaluating joint proprioception. The available devices range from simple goniometers to sophisticated and dependable isokinetic dynamometers with built-in electrogoniometers, including the Biodex, Kin-Com, Cybex, and Chattex models [14, 15].

Physioballs are often used in physiotherapy for balance and muscle training. Still, little scientific evidence supports their effectiveness, especially regarding immediate improvements in joint proprioception or muscle isokinetic parameters in sedentary individuals. A significant gap exists in earlier research on this topic. Few studies have clarified the long-term influence of physioball training on knee muscle activity and knee joint active repositioning senses without referencing isokinetic parameters or immediate effects [16–18].

Previous work has primarily focused on the long-term impact of physioball training on core muscle strength in women [19–21], with a smaller pool of research considering both males and females [22]. Moreover, very few studies have been conducted on the sedentary female adult population, particularly university students. Compared to other adult populations, university students generally behave more sedentarily, which might be due to personal, academic, technological, and socio-environmental factors. The inactive lifestyle seen among college students is largely shaped by several elements, which include inadequate access to proper exercise facilities, barriers like time limitations stemming from their academic workload, and concerns related to their health, such as being overweight or facing obesity, that can hinder their desire to engage in physical fitness activities [23]. Further, long-term sedentary behaviours have been shown to negatively impact lower limb function in healthy adult females, which may affect muscle strength and joint proprioceptive sensations [19].

To the authors' knowledge, very few studies have delved into the role of physioball wall squat training on knee joint active repositioning senses and isokinetic parameters. Most research has centred on lower extremity muscle activation and stability [24]. Given these gaps, there is clear relevance to studying the immediate effects of physioball wall squat training on knee joint active repositioning senses and isokinetic parameters in sedentary women. Insight into this area could inform preparation strategies for unexpected activities, improving joint awareness and preventing injury. Consequently, this study aims to assess the acute impact of physioball wall squat training on joint active repositioning senses and isokinetic parameters of knee flexion and extension in sedentary female university students. The authors chose the female population because knee joint injuries are particularly common in sports and daily activities in this population. Females are especially at risk due to differences in anatomy, structure, and sports participation. These disparities include variations in baseline conditioning, lower extremity alignment, physiological laxity, pelvic width, tibial rotation, and foot alignment [25]. The null hypothesis was that acute physioball wall squat training does not affect active joint repositioning senses and isokinetic parameters of knee flexion and extension in sedentary female university students.

Material and methods

Study design

A pre- and post-test experimental study design was adopted with a control group to investigate the short-term effects of physioball wall squat training on the active repositioning senses of the knee in college-aged female students. The study took place in the Physical Therapy Lab at the College of Applied Medical Sciences, Jouf University, between April 15, 2023, and November 15, 2023. The participants were split into two groups consisting of 30 members in each group. The isokinetic 4 Pro device was utilized to collect data on the same day and time of the intervention under the same circumstances. The device measured the isokinetic parameters of knee flexion and extension as well as the active knee joint repositioning senses.

Participants

A sample of 60 voluntary female college students was randomly divided into two groups, each comprised of 30 students. The control group (mean age 21.30 ± 1.56 years, mean height 158.03 ± 6.60 cm, mean body mass 56.73 ± 10.42 kg, and BMI 22.74 ± 3.86) was given a placebo (using a physioball without squatting) and the experimental group (mean age 20.77 ± 1.36 years, mean height 158.57 ± 6.36 cm, mean body mass 57.12 ± 9.24 kg, and BMI 22.52 ± 3.49) underwent physioball wall squat training. All participants were chosen from the College of Applied Medical Sciences, Jouf University. Table 1 illustrates the demographic data collected. The study population was comprised of women who led sedentary lifestyles (defined as any resting behaviour involving ≤ 1.5 metabolic equivalents of task energy expenditure, such as sitting, reclining, or lying down), except those who regularly cleaned their homes and exercised by walking. Subjects who lacked significant physical mobility in their daily lives and spent six or more hours a day sitting or lying down were included in the study.

The inclusion criteria for this study stipulated that all participants must be female college students, aged between 18 and 25 years, who have not engaged in any specific physical activity (i.e., they are sedentary subjects) for at least 6 months. As for the exclusion criteria, participants should not be pregnant at any stage, should not have a history of surgical procedures, and should not suffer from neuromuscular or musculoskeletal abnormalities (such as joint osteoarthritis or leg length discrepancy). Furthermore, they should not have any visual, vestibular, balance, cardiovascular, metabolic, rheumatic, or equilibrium disturbances that could affect the performance of the lower extremities. Additionally, participants should not have taken any medication that could affect equilibrium within 48 hours prior to the examination.

The necessary sample size was determined using G*Power software 3.1.9.4, with a confidence level of 95%, a power of 80%, and a moderate effect size of 0.3. The calculation indicated a minimum sample size of 54 participants. However, a total of 65 participants were selected for the study from the initial sample, only 60 subjects completed the study, as depicted in Figure 1. The subjects were randomized to physioball wall squat and control groups with a 1:1 allocation ratio, and it was performed using computer-generated random allocation cards (RANCODE®, IDV, Gauting, Germany). Each of the two groups of thirty subjects were assigned, and opaque, sealed envelopes were used to conceal the allocation.

Outcome variables

This study's independent variables were time (pre-test and post-test) and group (experimental and control). Conversely, the dependent variables included the knee's active repositioning senses error scores along with isokinetic markers of knee flexion and extension. Specific isokinetic measures included peak torque, peak torque to body weight ratio (the peak ratio of torque to body weight was used to normalize the data and eliminate any variation in peak torque amongst individuals due to body weight fluctuation), total work in maximal repetition, average power, average peak torque, and the agonist to antagonist ratio.

Blinding

The regulations of the study setting prevented the physiotherapist who conducted the experiment from being blindfolded. Blinding, however, took place during the assessment and data-gathering stages, as a physical therapy assistant who participated in the randomization was not involved in carrying out the therapeutic intervention or gathering data.

Table 1. Independent *t*-test of demographic data

Demographic variables	The control group (*n* = 30) mean ± *SD*	The experimental group (*n* = 30) mean ± *SD*	*t*-value	*p*-value
Age (years)	21.30 ± 1.56	20.77 ± 1.36	1.415	0.163
Body height (cm)	158.03 ± 6.60	158.57 ± 6.36	–0.319	0.751
Body mass (kg)	56.73 ± 10.42	57.12 ± 9.24	–0.152	0.880
BMI (kg/cm^2)	22.74 ± 3.86	22.52 ± 3.49	0.232	0.818

BMI – body mass index

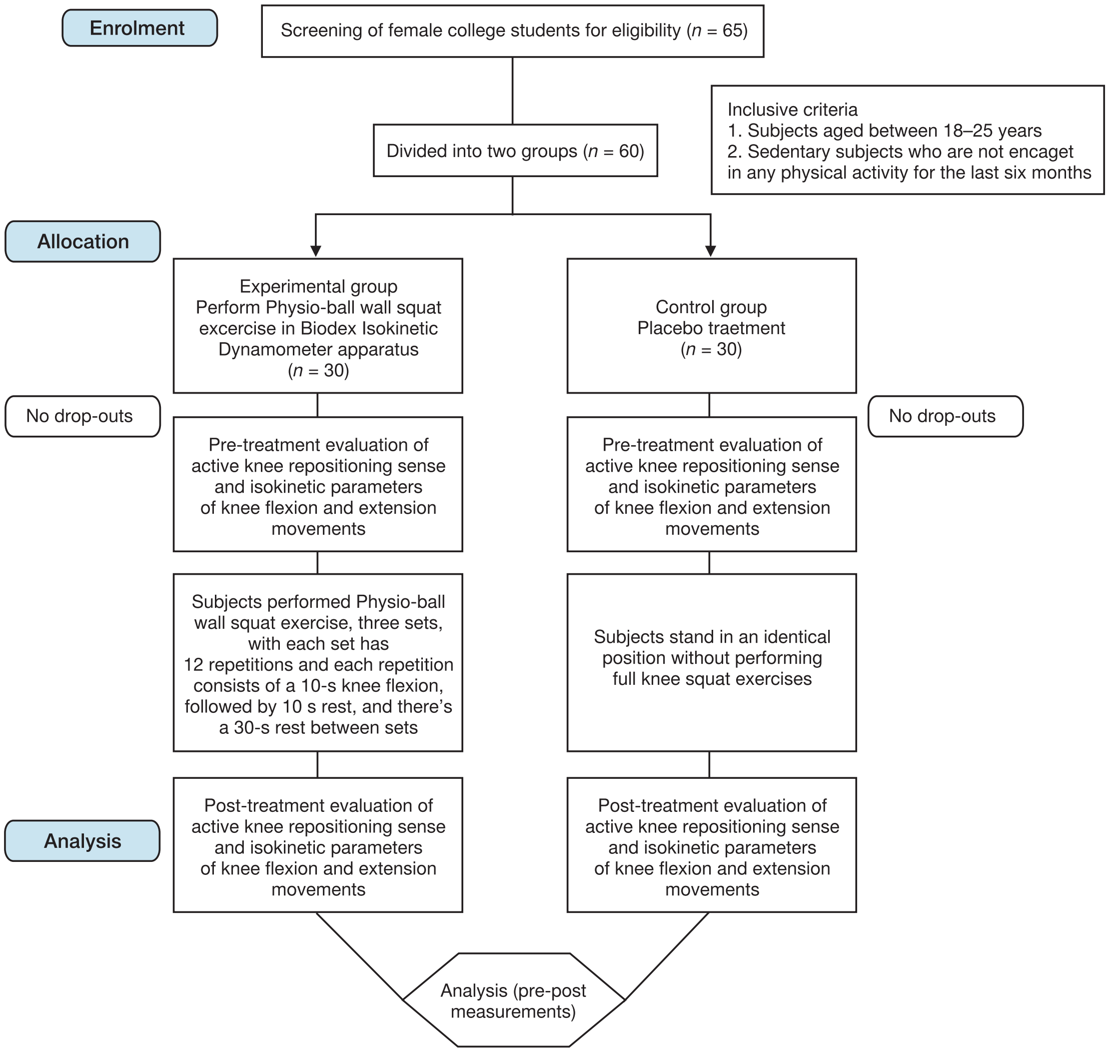

Figure 1. Flow chart of participants' involvement in the study

Instrumentation

The Biodex Isokinetic Dynamometer Multi-Joint System 4 Pro (Biodex Medical System Inc., Shirley, NY, USA) was used with a velocity of 60°/s to measure knee active repositioning senses from a knee flexion angle of 90 to 45° according to the recommendation in the device manual. The velocity of 60°/s was suitable for assessing the active repositioning senses of the knee to enable accurate targeting of the proper angle in the positioning senses and to prevent overshooting the target [26]. It also helped the authors to identify the isokinetic parameters of knee flexion and extension, as the velocity of 60°/s was commonly used in several previous studies [27, 28]. The dynamometer has proven reliable and valid for proprioception testing, as established by Unal et al. [29]. Furthermore, Riemann et al. [30] noted that data procured from this device are reliably accurate. Due to its reduced complexity, its adaptability to space constraints, and lower production cost, the Isokinetic Knee Dynamometer holds promise for improving clinical applications of knee evaluations. A study by Seven et al. [31] demonstrated a high test-retest reliability (inter-class correlation of 0.821) for joint active repositioning senses and muscle torque of the leading limb. Rauk-Kubacka et al. [8] emphasized the importance of choosing the right size and material for a Swiss ball for effective physioball wall squat training. Swiss balls are typically available in 55, 65, or 75 cm diameters. The selection should be based on the individual's body height to maintain proper alignment and balance during exercises. In this study, the authors conducted physioball wall squat training using a 55 cm physioball (Swiss Ball) compatible with all participant heights.

Procedure

Before the exposure to experimental interventions, all the participant's body heights were measured in meters using a tape measure and body mass was gathered with a digital scale in kilograms. Their body mass index (BMI) was then calculated using software that applied the formula of body mass (kg) divided by the square of body height (meters).

A Biodex Isokinetic Dynamometer 4 Pro was utilized to evaluate the initial active knee repositioning senses and isokinetic parameters of knee flexion and extension for both control and experimental group participants. Participants were instructed to sit erect on the dynamometer's adjustable chair for active knee repositioning senses detection. The chair was adjusted to a 90-degree rotation with a 110-degree back tilt (Figure 2).

The examined leg's lateral malleolus was aligned with both the knee joint's axis and the dynamometer's axis. Participants were told to wear loose, comfortable clothing to reduce the sensory signalling from the clothing's texture during the examination. The dominant leg (used for kickball) was examined, with only two experiment group participants having left leg dominance. Participants were instructed to close their eyes during the test to eliminate visual contributions and rely solely on deep knee sensation. Each session began with a 5-minute warm-up walking around the lab, and familiarization with the device was provided by demonstrating the movement to each participant.

The dynamometer's range of motion was measured from maximum knee extension to maximum knee flexion, with the zero position set at full knee extension. The participant's leg was then passively positioned at 90° of flexion by the examiner for each trial. Next, the participant actively moved their leg to the test angle of 45° of knee flexion at an angular velocity of 60° per second until stopped by the device. The participant was asked to focus on the sensation of the set angle for about 10 s. The examiner then passively returned the participant's leg to the starting position of 90° of knee flexion. The participant was instructed to move their leg to a 45-degree knee flexion angle and press a stop button once they reached the target angle. The device software calculated and recorded the error scores – the participant's ability to match the target angle – over three trials and presented the average error score in a printable PDF format. The same position and setup were used to measure the isokinetic parameters of knee flexion and extension, apart from a change in the program used for a concentric pattern of knee flexion and extension at an angular velocity of 60° per second.

The physioball wall squat exercise starts with the ball situated between the participant's back and the wall. Each participant from the experimental group should stand, slightly leaning on the ball with their knees lightly flexed, not fully extended. They then squat down slowly, causing the ball to roll down the wall while extending their arms and bending their knees until their thighs are roughly parallel to the floor (approximately 90° of knee flexion, Figure 3). Subsequently, they gently rise, allowing the ball to roll back up the wall. The training is comprised of three sets,

Figure 2. The measurement position for active knee repositioning senses and knee isokinetic parameters

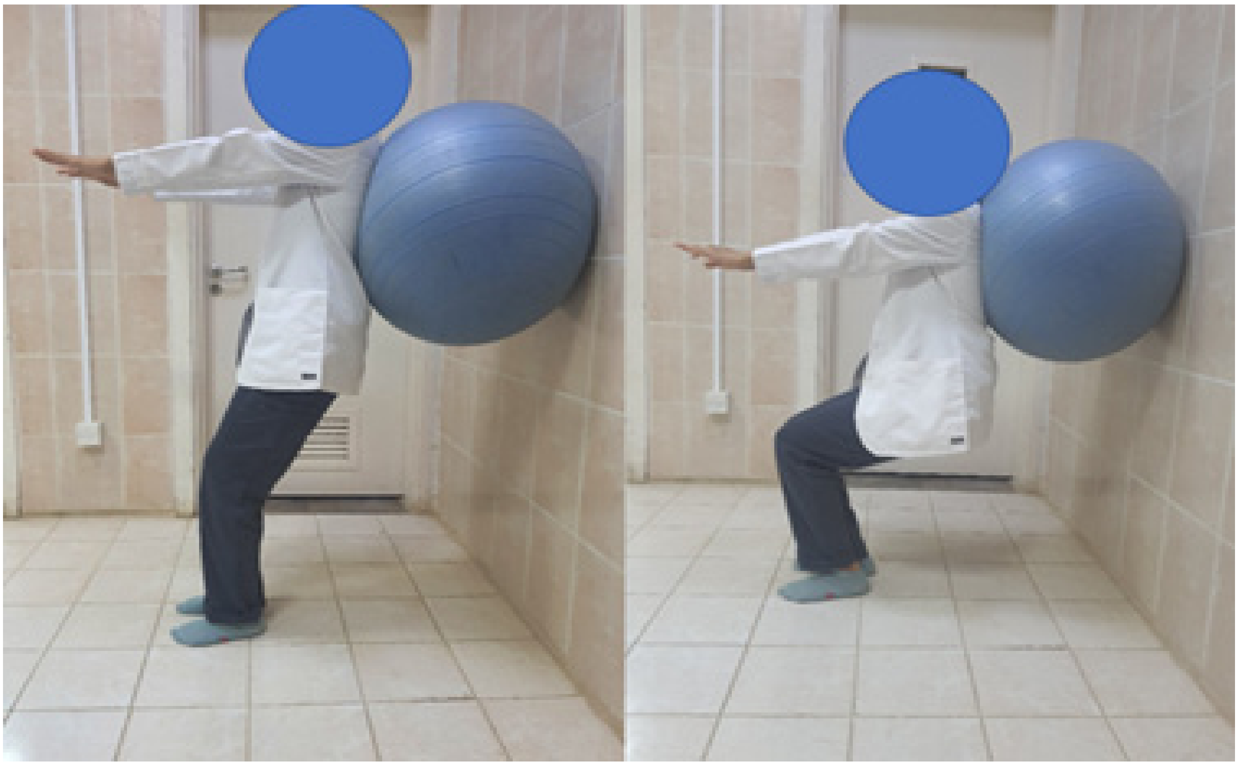

Figure 3. The start and the end positions of physioball wall squat exercises

with each set containing 12 repetitions. Each repetition consisted of 10 s of knee flexion, followed by 10 s of rest with a 30-second rest between sets [32].

For the control group, subjects started in an identical position as those in the experimental group, but they did not perform the knee squat (placebo intervention). After the physioball wall squat exercise, both groups underwent an evaluation for active knee repositioning senses and isokinetic parameters for knee flexion and extension, following the same pre-examination procedure.

Statistical analysis

The data analysis was carried out with the Statistical Package for Social Sciences (SPSS), version 20.0. Initially, data exploration and descriptive statistics were executed to confirm data normality in each group, which was tested with the Shapiro–Wilk test. An independent *t*-test was utilized to note the demographic differences between the control and experimental groups. Furthermore, the MANOVA test was applied to study the variations in error scores of active knee positioning senses and the isokinetic parameters of knee flexion and extension both between the experimental and control groups and within the groups for pre-and post-treatment interventions. The data from the 60 female collegiate students who completed the study were then analyzed. A significant difference was set at the alpha level of 5%.

Results

Independent *t*-test for demographic data

The Shapiro–Wilk test confirmed the demographic data's homogeneity across both groups. The demographic data's descriptive analysis revealed the mean and standard deviation (*SD*) for age, weight, height, and BMI, with no apparent outliers. Additionally, the independent *t*-test found no significant statistical differences in the demographic data between the two groups ($p > 0.05$), as shown in Table 1.

Multiple analysis of variance

Levene's test reveals no statistically significant variance between the two groups ($p < 0.05$). Prior to treatment, both the experimental and control groups showed equivalent mean error scores in active knee repositioning senses ($p = 0.686$). However, after treatment, there was a notable reduction in these types of errors [Active Knee Repositioning senses (error score)] in the experimental group compared to the control group ($p < 0.05$). While the control group displayed no significant change in active knee repositioning error scores post-interven-

Table 2. Active knee repositioning senses and isokinetic parameters of knee extensors at an angular velocity of 60°/s within and between groups

Variables		Experimental group (*n* = 30) mean ± *SD*	Control group (*n* = 30) mean ± *SD*	*F*-value	*p*-value
Active knee reposition sense (error score)	pre	4.12 ± 1.77	3.93 ± 2.02	0.165	0.686
	post	2.57 ± 1.12	4.37 ± 1.88	15.995	< 0.05*
	F-value	11.85	0.927	–	–
	p-value	< 0.05*	0.338	–	–
Peak torque (N-M)	pre	74.44 ± 7.45	73.64 ± 7.41	0.108	0.743
	post	85.33 ± 13.64	73.60 ± 7.45	23.441	< 0.05*
	F-value	20.216	0.027	–	–
	p-value	< 0.05*	0.890	–	–
Peak TQ/BW (%)	pre	83.96 ± 5.25	82.21 ± 5.53	1.362	0.246
	post	121.72 ± 6.54	81.76 ± 5.78	713.02	< 0.05*
	F-value	636.789	0.090	–	–
	p-value	< 0.05*	0.764	–	–
Max rep TOT work (J)	pre	72.52 ± 9.79	71.56 ± 11.21	0.145	0.704
	post	87.80 ± 8.14	70.47 ± 9.44	47.813	< 0.05*
	F-value	37.186	0.190	–	–
	p-value	< 0.05*	0.663	–	–
Avg. power (W)	pre	41.06 ± 5.18	41.30 ± 5.18	0.035	0.852
	post	55.40 ± 4.71	41.92 ± 5.20	105.075	< 0.05*
	F-value	118.906	0.217	–	–
	p-value	< 0.05*	0.642	–	–
Avg peak TQ (N-M)	pre	61.40 ± 8.17	57.79 ± 8.59	2.987	0.087
	post	87.91 ± 7.25	57.89 ± 8.27	206.966	< 0.05*
	F-value	161.403	0.021	–	–
	p-value	< 0.05*	0.896	–	–

TOT – total work, TQ/BW – torque/body weight, TQ – torque
* level of significance at $p < 0.05$

tion ($p = 0.338$) in comparison to pre-intervention, the experimental group experienced a significant reduction following the physioball wall squat training ($p < 0.05$), as depicted in Table 2.

Conversely, peak torque, peak torque to body weight ratio, total work in maximal repetition, average power, and average peak torque of knee extensors at an angular velocity of 60°/s exhibited a statistically significant increase post-intervention for both the experimental and control groups ($p < 0.05$), the increase favoured the experimental group, a trend also noticed in the pre-and post-intervention analysis of the experimental group alone. This information is outlined in Table 2.

Similarly, peak torque, peak torque to body weight ratio, total work in maximal repetition, average power, and average peak torque of knee flexors at an angular velocity of 60°/s indicated a statistically significant increase post-intervention between the experimental and control groups ($p < 0.05$), also favouring the experimental group – a trend mirrored in the pre- and post-intervention assessment within the experimental group only. However, the agonist-antagonist ratio displayed a significant reduction in the experimental group compared to the control group following physioball wall squat training and in the post-intervention of the experimental group alone, as detailed in Table 3.

Discussion

The purpose of this study was to analyze the short-term impact of physioball wall squat training on active knee repositioning senses and knee isokinetic parameters among sedentary women. The study found no significant variance in pre-training between the control and experimental groups across all assessed variables. However, notably significant improvements were observed post-training for all isokinetic parameters and error scores in favour of the experimental group.

Table 3. Isokinetic parameters of knee flexors at an angular velocity of 60°/s within and between the groups and agonist-antagonist ratio

Variables		Experimental group (n = 30) mean ± SD	Control group (n = 30) mean ± SD	F-value	p-value
Peak torque (N-M)	pre	41.47 ± 4.42	40.55 ± 4.31	0.649	0.422
	post	45.55 ± 4.48	39.73 ± 4.36	26.32	< 0.05*
	F-value	12.973	0.523	–	–
	p-value	< 0.05*	0.471	–	–
Peak TQ/BW (%)	pre	46.74 ± 3.24	46.65 ± 4.08	0.011	0.917
	post	49.40 ± 2.35	45.56 ± 3.83	18.719	< 0.05*
	F-value	8.967	1.506	–	–
	p-value	0.003*	0.222	–	–
Max REP TOT work (J)	pre	38.57 ± 4.54	38.71 ± 3.36	0.017	0.896
	post	42.76 ± 5.76	40.25 ± 3.12	5.094	0.027*
	F-value	14.069	1.884	–	–
	p-value	< 0.05*	0.173	–	–
Avg. power (W)	pre	24.38 ± 5.09	24.23 ± 5.10	0.12	0.915
	post	28.51 ± 6.30	25.44 ± 5.50	4.628	0.034*
	F-value	8.381	0.725	–	–
	p-value	0.005*	0.396	–	–
AVG peak TQ (N-M)	pre	24.38 ± 5.09	24.23 ± 5.10	0.322	0.572
	post	28.51 ± 6.30	25.44 ± 5.50	4.833	0.030*
	F-value	13.223	0.758	–	–
	p-value	< 0.05*	0.386	–	–
AGON/ANTAG ratio (%)	pre	55.89 ± 5.53	57.03 ± 6.54	0.621	0.432
	post	41.11 ± 3.29	55.68 ± 6.39	101.887	< 0.05*
	F-value	104.894	0.876	–	–
	p-value	< 0.05*	0.351	–	–

TOT – total work, TQ/BW – torque/body weight, TQ – torque
* level of significance at p < 0.05

Moreover, substantial improvements in error scores for active knee repositioning senses and isokinetic parameters for knee flexors and extensors were observed post-physioball wall squat training in the experimental group, compared to pre-training levels. In contrast, the control group showed no significant statistical changes in these scores post-intervention compared to pre-training. These findings highlight the immediate benefit of physioball wall squat training in enhancing active knee repositioning senses and isokinetic parameters for knee flexors and extensors in sedentary women. Therefore, by enhancing joint function and deep sensations, physioball knee squat training may reduce the risk of injury during unexpected physical activities. This conclusion is supported by the findings of Palekar et al. [33], which demonstrated improved lower limb muscle power and balance when standing due to increased muscle strength following wall squat and ball squat training, which also reduced fear of falling. The application of physioball wall squat training and the sample selection, which included senior subjects, were the differences between this study and the current study.

Our study's findings align with those of a study conducted by Setyawan et al. [34], which investigated the effects of ground and Swiss ball exercises using the circuit exercise method over 8 weeks on a student's balance, strength, flexibility, and muscle endurance. The study reported a significant post-training effect. Physioball exercises place the joints in unstable situations, causing the body to experience stress to maintain stability throughout its movements. Such exercise stimulates sensations in the deep knee (proprioception), which integrates with various sensory-motor centres to regulate automatic muscle contractions, thus preserving body balance [19]. As a result, acute alterations in muscle-tendon unit length, tension, muscle force production, and neuromuscular activity can alter the capacity to perceive and react to muscle activity, leading to immediate changes in balance and muscle strength [35].

An instability training program using Swiss balls with body mass resistance can lead to sustained improvements in joint proprioception and core strength, which are beneficial to general health and performance [19]. Moreover, another study reaffirms the advantages of Swiss ball training in conjunction with conventional physiotherapy, demonstrably improving balance and mobility and enhancing quality of life in post-stroke patients. However, this patient population differs from those in the current study [36]. Swiss ball exercises have been found to positively affect the strength of abdominal, back, and leg muscles, spine and hip flexibility, as well as static and dynamic balance. This was highlighted in a study examining the correlation between karate performance and the impact of Swiss ball exercises on various physical and physiological parameters [37]. While most of the previous research has focused on the effects of the Swiss ball on core stability and strength [38, 29], our study endeavoured to ascertain its influence on the knee joint, which is the body's most frequently injured lower limb joint.

The primary limitation of our study was that it only included sedentary college students aged 18–25, meaning the results only extend to this specific demographic. We also did not carry out a gender comparison which may affect the generalizability of the results. Additionally, because tests and training occurred in lab environments, external factors could have affected the outcomes. The study only utilized one angular velocity. Future studies should consider using multiple angular velocities to identify variations in joint position sensation and knee isokinetic parameters. Including different joint position senses, like passive knee senses, and examining other groups, like athletes, elderly adults, and individuals with balance disorders, may also provide more comprehensive results.

Conclusions

In conclusion, a sedentary woman's knee flexor and extensor isokinetic parameters can be successfully improved by short-term physioball wall squat training with body mass as resistance. Furthermore, for women who are not trained, using body mass physioball wall squat training leads to notable improvements in knee proprioception by increasing the perception of knee active repositioning, which enhances joint awareness and lowers the risk of injury. According to this, teaching untrained women the physioball wall squat can improve knee joint function and awareness, cause notable changes in their neuromuscular system, and reduce the likelihood of injuries. Additional investigation is required to validate the impact of physioball wall squat training with varying knee joint angles and types of muscle contractions in various populations, including older adults and athletes.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the College of Applied Medical Sciences, Jouf University (approval No.: 7-04-44).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

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