

Research Paper

Efficacy of Swiss Ball Exercises on Motor Control and Defensive Blocking Handball Players With Hamstring Strain Injury

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ABSTRACT

Objectives: This study aimed to investigate the efficacy of a Swiss ball rehabilitation program on motor control and defensive blocking performance in handball players with grade I hamstring strain injuries.

Methods: This was a pre-post single-group interventional study. A total of 32 professional and semi-professional handball players from Baghdad Premier League clubs were enrolled, with 21 completing the entire 8-week intervention. The rehabilitation program consisted of six Swiss ball exercises performed four times weekly to enhance hamstring strength, hip joint flexibility, and defensive blocking performance. Statistical analyses were performed using paired t-tests and Cohen's d effect sizes.

Results: Significant improvements were observed in all outcome measures: Perceived hamstring strength in relaxed (+1.1 units, $P=0.013$) and tensed (+2.3 units, $P=0.001$) states, hip joint range of motion (ROM) (+9.3°, $P=0.004$), and defensive wall block performance (+3.5 blocks/15s, $P<0.001$). The effect sizes ranged from medium to large; the largest was for defensive blocking ($d=2.02$).

Discussion: These findings demonstrate that Swiss ball training effectively enhances neuromuscular control, functional mobility, and sports performance in handball players with hamstring injuries. The limitations of this study are its short-term follow-up and single-group design. Future randomized controlled trials are recommended to compare Swiss ball rehabilitation versus normal treatments and to study long-term consequences.

Keywords:

Swiss ball exercises, Hamstring injury, Motor control, Handball, Rehabilitation

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Highlights

- An 8-week Swiss ball rehabilitation program significantly improved hamstring function in handball players with grade I injuries.
- Key outcomes included enhanced hamstring strength, hip joint ROM, and defensive blocking performance.

Plain Language Summary

This study analyzed the effectiveness of a certain Swiss ball exercise in rehabilitating handball players with mild hamstring strains. Handball players are prone to hamstring strains from sudden movements and hard defensive actions, such as shot blocking. The researchers worked with professional and semi-professional handball players in Baghdad and designed an 8-week rehabilitation program using Swiss ball exercise. They enhance muscle strength, flexibility, and balance by challenging the body to work more intensely on an unstable surface.

Introduction

In the last few decades, sports rehabilitation and sports medicine have been transformed by advances in biomechanics, technology, and interprofessional practices for injury management [1, 2]. Modern practices in contemporary rehabilitation are today aimed not only at speedy recovery but also at readmission of sportspersons to pre-injury level performance through evidence-based sport practice [3]. These advances have played a central role in balancing the complex interplay among mechanisms of injury, sport-specific prevention, and functional rehabilitation [4], particularly for sports with high injury risk like handball, where sudden deceleration changes, violent sprinting, and impact defensive maneuvers make the athlete susceptible to hamstring strain injury (HSI) [5, 6].

HSIs remain a current problem in handball, accounting for 12–15% of total sports injuries and tending to result in prolonged recovery and impact technical performance through ruptured training cycles [7, 8]. The physical stresses of handball, such as sudden decelerations and accelerations, and defense techniques, such as the block wall, expose the hamstring muscles to significant stress [9]. The block wall, a cornerstone of modern defensive play, relies on pinpoint coordination, explosive power, and dynamic stability to extinguish shots and initiate counterattacks. However, poor biomechanics or residual weakness from an injury can get in the way of this capacity, compromising personal and team performance [10].

Traditionally, rehabilitation programs have focused on the maintenance of muscle strength and range of motion (ROM), but more recent evidence indicates that balancing neuromuscular training to counter functional imbal-

ances and avoid the risk of re-injury is necessary [10–12]. Recent technological and methodological advancements have revolutionized rehabilitation models, and Swiss ball exercises have become a cornerstone intervention to enhance neuromuscular control and functional rehabilitation in sports [13, 14]. The Swiss ball hamstring curl and wall squat are specific exercises aimed at improving hamstring strength, core stability, and dynamic balance by co-activating various muscles on unstable surfaces [15]. Experiments demonstrate that Swiss ball training can improve trunk extensor/flexor endurance, lower limb coordination, and control of the lumbopelvic region, which are crucial to prevent HSI and optimize sport-specific movement patterns, such as the block wall technique during handball [16, 17].

Although eccentric training was initially found useful in the prevention and rehabilitation of HSI, existing protocols fail to incorporate sport-specific neuromuscular training and biomechanical specificity, which are necessary for returning functional performance in defensive movements such as the block wall [18]. Swiss ball exercise, in its capacity to optimize eccentric-concentric activation of the muscles and dynamic stabilization [19].

By prioritizing hip joint mobility, hamstring strength, and lumbopelvic control, this intervention focuses on the performance demands of handball's high-impact defensive maneuvers, which are commonly interrupted after injury [20]. In addition, the study's focus on quantifying motor control adjustments and defensive blocking effectiveness is congruent with the increasing imperative to relate clinical outcomes to sport-specific performance measures.

Materials and Methods

This single-group pre-post prospective study adhered to the consolidated standards of reporting trials statement. The population was Baghdad Premier League club players, namely Al-Talaba, Al-Jaish, Al-Shurta, Al-Karkh, and Al-Hashd clubs. The assessment was conducted at the College of Physical Education and Sports Sciences from January 2023 to June 2024. The study was conducted per the principles of the Declaration of Helsinki. All eligible participants provided written informed consent and received a copy of their executed consent form for their personal records. The participants were informed that they could withdraw from the study at any point without obligation. Adverse effects (e.g. increased pain) were also noted.

Population

A priori power analysis (G*Power software, version 3.1.9.7) indicated a required sample size of $n=28$ to detect a medium effect size ($d=0.6$) in hamstring strength gains with 80% power ($\alpha=0.05$). To allow for a 15% dropout, 32 participants were recruited.

The participants eligible for this study were athletes aged 18-35 years with a grade I hamstring injury diagnosis confirmed by magnetic resonance imaging (MRI) and clinical examination conducted by a physician. They had no prior history of recurrent hamstring injuries or surgical interventions and were engaged in professional or semi-professional handball. All participants provided

written informed consent prior to the study [21]. The exclusion criteria included evidence of grade II or grade III hamstring injury, other lower limb musculoskeletal injuries affecting movement or performance, a history of neurological or orthopedic conditions impacting gait or balance, or an inability to comply with necessary procedures.

Assessments

The participants were evaluated at two time points: Pre-intervention and post-intervention. They were recruited over eight weeks. After initial screening (demographic data collection, and physical examination), they were recruited for the study. The study outcomes were hip joint ROM, hamstring muscle strength, and defensive blocking performance in handball. The study flow diagram is shown in Figure 1.

The hip joint ROM was recorded following a protocol standardized for validation by expert consensus [22]. Measurements were taken 1–3 days post-injury to standardize acute-phase measurements. A Casio cinematic camera (Casio Computer Co., Ltd., Tokyo, Japan; 25 frames per second) mounted on a tripod was used to record the joint angles during active hip flexion and extension movements. Adhesive markers were placed on anatomical landmarks (lateral femoral condyle, greater trochanter, and anterior superior iliac spine) to enhance the precision of movement measurement [23].

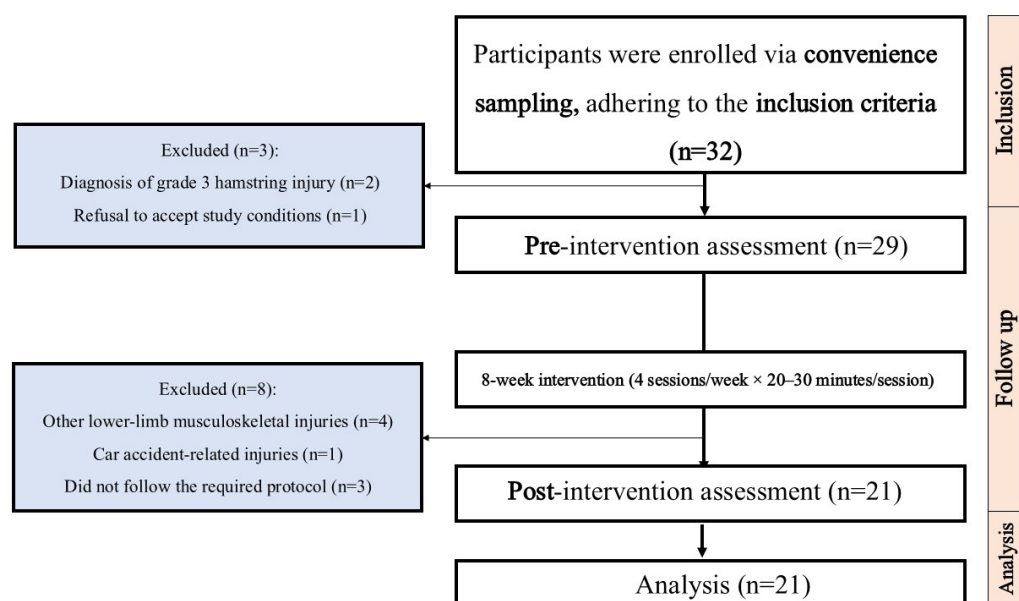


Figure 1. Study flow diagram

Participants performed slow, controlled flexion and extension movements of the affected limb while supine on a medical examination table, moving to their maximum pain-free range. Video recordings were analyzed using Kinovea software (version 0.9.2; open-source software developed by Olivier Rossel, France) to measure hip joint angles (intraclass correlation coefficient [ICC]=0.79) [24]. Goniometric measurements were cross-referenced with a panel of three sports medicine experts to maintain adherence to accepted biomechanical criteria. A blinded examiner performed all measurements to limit measurement bias.

Hamstring muscle strength was measured using a handheld force sensor unit (MicroFET2 Dynamometer, Hoggan Scientific, Salt Lake City, USA), which is a valid measure of peak force production in Newtons. The participants were positioned prone on a medical examination table. During the relaxed condition test, the knee was kept in full extension to measure baseline muscle tone and passive resistance. The examiner placed the force sensor over the posterior distal femur and applied minimal pressure without eliciting any voluntary contraction from the participant [25].

For the tensed state test, the participants flexed their knees to approximately 30°, which was considered the optimum mid-range position for hamstring activation. Under these conditions, the participants were requested to maximally contract their hamstring muscles against the resistance of the force sensor. Three maximal voluntary isometric contractions (MVICs) were performed for each limb by each participant, with 30 seconds of rest between trials to minimize fatigue and ensure consistency of effort between repetitions (ICC=0.89 for relaxed and ICC=0.92 for tensed) [26].

Defensive blocking performance was evaluated using a standardized protocol adapted from validated handball-specific functional tests. The test evaluates an athlete's ability to execute repetitive defensive blocks with technical precision, speed, and consistency in game-like conditions.

The test was conducted on a standard handball court. Two handballs were suspended from goalposts at a height of 2.6 meters, which could be adjusted downward for youth or female athletes. Adhesive tape markers were used to designate the 6-meter line, vertically aligned with the suspended balls, and two goalposts on the 8- to 9-meter line, 3 meters apart. A middle starting point was designated halfway between the two balls. Players

began each trial from a stationary standing position at this location.

On a visual start signal, players performed a cycle consisting of a forward sprint, a jumping block to touch one of the balls with both hands, a controlled landing, and recovery to the starting position as fast as possible. This cycle was repeated as many times as possible within 15 s. All movements had to replicate real-game defense mechanics, including correct arm position, explosive jumping, and controlled direction changes.

Some performance criteria were utilized to uphold reliability and validity. Bilateral hand contact on the ball must be made on each block attempt. Each movement must be initiated from the established starting position, and any deviation invalidates that repetition. Attempts that did not meet these criteria (single-hand contact or a step outside the established area) were considered invalid and were not counted in the scoring. Scoring was based on the number of successful defensive blocks completed within 15 s [27].

Intervention

The rehabilitation program comprised Swiss ball exercises to improve hamstring flexibility, elasticity, and strength. The program lasted 8 weeks, with the participants attending four sessions per week, each lasting 20–30 minutes. The exercises were designed to progress from simple to complex movement patterns based on the functional demands of the participants. The sessions started with a warm-up, proceeded with the main Swiss ball exercises, and concluded with a cool-down phase [28]. Tables 1 and 2 present a detailed explanation of the model and exercise protocol.

Statistical analysis

Statistical analysis was performed using SPSS software, version 25 (IBM Corp., USA). Descriptive statistics were employed to describe the participants' demographic and baseline characteristics. Normality test of data was conducted using the Shapiro-Wilk test. For variables in normal distribution, a paired t-test was utilized.

To compare the outcome measures (i.e. ROM of the hip joint, hamstring strength, and defensive blocking performance) before and after the intervention, a paired-samples t-test was used. Statistical significance was set at $P < 0.05$. Results were reported as Mean $\pm$ SD, and effect sizes were calculated using Cohen's d to allow for comparison of the size of change.

Results

Participant demographics

21 handball players (mean age: 24.6 ± 3.2 years) with Grade I hamstring injuries were included in the study. Baseline demographic and injury-related characteristics are shown in Table 3. All subjects were competitive players in the Baghdad Premier League, with 6.5 ± 2.1 years of competitive handball experience. Injuries were observed most frequently in the dominant limb (62.5%) in high-level defensive play or sprinting activities of play. Shapiro-Wilk test confirmed normal distribution of baseline data ($P > 0.05$).

As seen from Table 3, all the variables improved statistically significantly ($P < 0.05$) with different effect sizes ranging from medium to large, which illustrates variability in the responsiveness of clinical and functional measures. The Defensive Wall Block evidenced the largest effect size ($d = 2.02$), illustrating that Swiss ball training effectively integrates hamstring strength, hip mobility, and sport-specific neuromuscular control in enhancing defensive ability. In contrast, perception of resting state hamstring strength ($d = 0.61$) and range of hip joint motion ($d = 0.77$) were affected mediumly.

Discussion

Significant improvements were found in all measured outcomes following the 8-week Swiss ball rehabilitation program. As shown in Table 4, perceived hamstring strength increased in both relaxed (pre: $4.1 \pm 0.8 \rightarrow$ post: 5.2 ± 0.7 ; $P = 0.013$) and tensed states (pre: $3.9 \pm 1.0 \rightarrow$ post: 6.2 ± 0.9 ; $P = 0.001$), hip joint range of motion improved ($67.5 \pm 4.3^\circ \rightarrow 76.8 \pm 3.9^\circ$; $P = 0.004$), and defensive wall block showed the greatest gain ($5.0 \pm 1.2 \rightarrow 8.5 \pm 1.0$; $P < 0.001$). Effect sizes ranged from medium to large,

indicating strong practical relevance. These outcomes reflect the effectiveness of the structured Swiss ball rehabilitation protocol in enhancing hamstring strength, flexibility, and functional performance through progressive exercises that promoted faster recovery and improved neuromuscular control.

Gains observed are consistent with biomechanical and neuromuscular benefits of unstable surface training. Swiss ball training, with dynamic stabilization, eccentric-concentric activation of the muscles, and proprioceptive feedback, most likely increased hamstring neuromuscular effectiveness and joint mobility [29]. The substantial overall effect size on defensive wall block performance suggests successful transfer of strength and flexibility adaptations to sport-specific performance, in particular reactive agility and explosive power—both crucial to handball defense [30].

Medium effects on passive hamstring qualities (relaxed-state strength sensation and range of motion) reflect the lagging adaptation of muscle stiffness and connective tissue compliance to dynamic training [29]. Passive flexibility gains may require longer interventions or adjunct therapy (e.g. foam rolling, static stretching) to achieve equivalent improvements to active neuromuscular outcomes. The findings provide further support to current evidence that unstable surface training provides increased prominence on neuromuscular coordination at the cost of passive tissue adaptation [31].

The diversity of rehabilitation exercises, their gradual progression from easy to difficult, and the commitment of the participants significantly contributed to the recovery process. When designing the rehabilitation exercises, the researcher should ensure a gradual approach to help the affected hamstring muscles adapt without causing pain, thereby facilitating effective recovery [7].

Table 1. Exercise implementation model

Exercise	Repetitions	Sets	Rest Between Repetitions (s)	Rest Between Sets (s)
1	12	4	30	120
2	12	4	30	120
3	12	4	30	120
4	10	4	30	120
5	10	4	30	120
6	10	4	30	120

Table 2. Exercise execution protocol

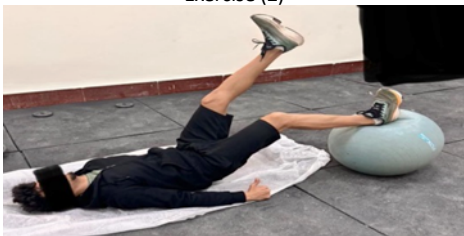
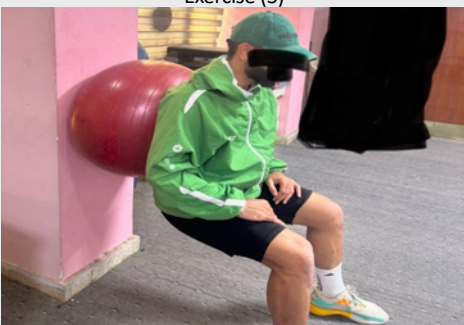
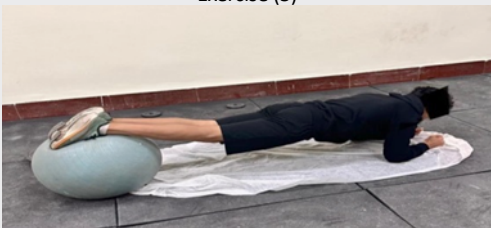
Exercise (1) 	Stability ball hamstring curl exercise Lie flat on the floor, with the back of your lower legs resting on a stability ball and your legs fully extended. Engage your core muscles and squeeze your glutes to lift your hips off the ground, forming a straight line from your shoulders to your feet. This is the starting position. Pull your heels toward you, rolling the ball as close to your glutes as possible or until your knees form a 90-degree angle. Pause briefly, then slowly extend your legs, rolling the ball away while maintaining control and engaging your glutes. Return to the starting position and repeat.
Exercise (2) 	Single-leg stability ball bridge Lie on your back on the floor, feet resting on a stability ball, and knees bent at a 90-degree angle. Keep your arms straight on the floor beside you for support. Lift one foot off the ball and extend it straight. Engage your glutes and press through the heel of the supporting leg to lift your hips off the ground. Tighten your core to keep your torso straight from your head to your knees. Pause briefly at the top, then slowly lower your hips back to the ground. Complete all repetitions on one leg before switching to the other side.
Exercise (3) 	Stand with your feet hip-width apart and place a stability ball between the middle of your back and the wall. Your feet should be positioned slightly before your body; this is your starting position. Bend your knees to lower your body along the ball until your thighs are parallel to the floor. Ensure your knees are aligned with your mid-toes. Pause briefly, then press your heels to return to the starting position and repeat. To increase the difficulty, a dumbbell was held in each hand.
Exercise (4) 	We placed the plank position on the Swedish ball, where the support is on the arms, while maintaining stability. The athlete's body must remain straight, avoiding any bending of the legs.
Exercise (5) 	We placed the plank position on a Swedish ball, ensuring the legs rested on the ball for stability. The athlete must maintain a straight body alignment without bending the legs.
Exercise (6) 	The athlete lies face down on the ground while an assistant holds the Swedish ball. The athlete then attempts to strike the ball using both legs.

Table 3. Baseline demographic and injury-related characteristics

Variables	Mean±SD/No. (%)
Age (y)	24.6±3.2
Height (cm)	178.4±5.7
Weight (kg)	76.2±6.9
Training experience (y)	6.5±2.1
Injury side	Right (13, 62.5)/left (8, 37.5)
Injury mechanism	Sprinting (9, 42)/defensive blocking (12, 57)
Time since injury (d)	1.8±1.2
Position on team	Wing (7, 37.5)/backcourt (14, 62.5)

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The researcher followed a gradual rehabilitation process for the hamstring muscles, yielding positive results. The principle of gradual progression serves as a safeguard against internal joint and muscle tendon disorders, preventing muscle spasms [7, 8]. The duration of treatment and rehabilitation varies depending on the injury type, location, and treatment methods used. It is crucial to complete the rehabilitation period to ensure full recovery [29].

Conclusion

This study highlights the Swiss ball rehabilitation program as a valuable method for recovering hamstring function, hip mobility, and defensive performance in handball players following injury. Despite the large effects of dynamic and neuromuscular measures, the medium effects of passive properties demonstrate the need for multimodal strategies to elicit tissue-level adaptations.

Study limitations

Single-group pre-post design: Without a control group, causal inferences about the intervention's efficacy are extensive. Short-term follow-up: Retention of clinical gains over the long term and re-injury rates remain untested, limiting conclusions about sustained clinical relevance.

Future research recommendations

Randomized controlled trials: Compare Swiss ball rehabilitation with conventional protocols (e.g. eccentric training) to establish its unique benefits. Advanced biomechanical quantities: Use 3D motion analysis, muscle architecture imaging (e.g. MRI/ultrasound), and force plate kinetics to quantify passive and active adaptation.

Table 4. Paired t-test and effect size results

Variables	Mean±SD		t	P	Effect Size (Cohen's d)
	Pre	Post			
Perception of hamstring strength (relaxed state)	4.1±0.8	5.2±0.7	-3.24	0.013	0.61 (medium)
Perception of hamstring strength (tensed state)	3.9±1	6.2±0.9	-5.89	0.001	1.67 (large)
ROM (hip joint, °)	67.5±4.3	76.8±3.9	-4.1	0.004	0.77 (medium)
Defensive wall block (n/15 s)	5±1.2	8.5±1	-7.15	0	2.02 (large)

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Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Scientific Research Ethics Committee of **Al-Mustansiriya University**, College of Physical Education and Sports Sciences (Code: 35, April 28, 2023). Comprehensive ethical guidelines were adhered to, ensuring the safety and well-being of all participants. This includes obtaining informed consent from all participants and their legal guardians.

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Authors' contributions

Conceptualization and supervision: Alaa Mohammed Jasim; Methodology, data collection and data analysis: Ghufuran Zaid Aziz; Writing the original draft and review: All authors.

Conflict of interest

The authors declared no conflict of interest.

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