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BALANCE AND STRENGTH IN NONPROFESSIONAL DANCERS WITH SNAPPING HIP: A CROSS-SECTIONAL STUDY

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ABSTRACT

Snapping hip syndrome (SHS) is prevalent among dancers, affecting their well-being and increasing injury risk. Little is known about SH and its relationships with factors commonly associated with injury. The study aimed to describe and compare (affected vs. unaffected sides) dynamic balance, hip muscle strength, functional turnout (FTO), compensated turnout (CTO) and passive hip external rotation (HER) range of motion (ROM) in nonprofessional dancers with SH and explore interrelationships. The cross-sectional study included a convenience sample of adult and adolescent nonprofessional dancers diagnosed with SH, from multigenre dance schools in Cape Town, South Africa. Demographic information was collected. Outcome measures were the numeric pain rating scale (pain), Y balance test (dynamic balance), goniometry (active and passive HER) and handheld dynamometry (hip muscle strength). Affected and unaffected sides were randomly tested. Statistical analyses included paired t-tests for side-to-side comparisons, one-way analysis of variance (ANOVA) for age comparisons across pain categories, and Pearson's correlation coefficients to explore relationships between variables. Twenty-three women voluntarily participated (mean age: 22 (6.4) years). Study outcomes did not differ between affected and unaffected sides (p=0.28–0.70). HER muscle strength on the affected side and CTO demonstrated a moderate positive correlation (r=0.51, p=0.01), suggesting that improving HER muscle strength will improve FTO.

***Keywords*:** Compensated turnout; Cross-sectional descriptive study; Dancers; Dynamic balance; Hip pain.

INTRODUCTION

Snapping hip (SH) or coxa saltans is common among dancers but is often overlooked because some dancers ignore painful injuries and prioritise competitive advantage over taking time off or seeking medical advice (Jacobs *et al.*, 2017). This is concerning, given the risk of reinjury (Kenny *et al.*, 2019) and the ultimate impact on dancers' quality of life (Gross *et al.*, 2018). Unfortunately, potentially modifiable factors contributing to the SH injury that could inform early screening and prevention strategies are poorly understood. Specifically, little is known regarding balance – an essential skill for dancers – and its relationship with modifiable factors such as muscle strength (Martinez *et al.*, 2014).

Snapping hip occurs when hip joint movement produces a snapping sound (Yen *et al*., 2015; Via *et al*., 2017). When pain and inflammation are present, it is referred to as SH syndrome (SHS) (Laible *et al*., 2013; Flato *et al*., 2017). In this paper, SH refers to both presentations of the condition, namely, with and without pain. The causes of SH are multifactorial and can be intra-articular, developing after a traumatic event (Wahl *et al*., 2004; Yen *et al*., 2015), or extra-articular, having an insidious onset with two generally accepted forms: internal snapping hip (ISH) and external snapping hip (ESH) (Lewis, 2010). The pain associated with extra-articular SH could be the result of repetitive snapping of the tendons and is, therefore, considered an overuse injury (Cheatham *et al*., 2015). Snapping hip is found in 5%–10% of the general population (Cheatham *et al*., 2015; Yen *et al*., 2015; Witke-Wozniak *et al*., 2016) but may be more prevalent in athletes such as soccer players, runners, weightlifters and dancers, whose sport requires an extreme hip flexion range (beyond 90 degrees) (Lewis, 2010; Via *et al*., 2017). In soccer, hip injuries usually occur in the preseason when the training intensity increases at those extreme ranges of motion (ROM) (Wahl *et al*., 2004). Runners typically present with ESH, while dancers and artistic athletes typically develop ISH (Walker *et al*., 2021).

Artistic athletes, such as dancers, figure skaters, and gymnasts, are more susceptible to hip injuries compared to runners, soccer players, and the general population, and most of these injuries are considered overuse injuries (Smith *et al*., 2015). This is likely due to the repetitive hip movements that are performed at extreme ROM and in different hip positions (Lewis, 2010; Bolia *et al*., 2018). In a sample of 87 ballet dancers, 90% reported an SH (Winston *et al*., 2007). The incidence of SH in artistic athletes is not well defined, although it has been reported to be significantly higher in female student dancers and nonprofessional dancers than in professional dancers (Potalivo & Bugiantella, 2017). A systematic review identified three main injury predictors in dance, namely functional turnout (FTO), passive hip external ROM and compensated turnout (CTO) and provided evidence for their use as predictive screening tests for lower limb injuries (Armstrong & Relph, 2018). Functional turnout is the position that the dancer assumes when the lower limbs are externally rotated at the hip joint and the feet point in opposite directions. The ideal turnout angle is difficult to attain, and dancers often compensate elsewhere to accommodate for the lack of turnout ROM (Coplan, 2002; Champion & Chatfield, 2008). This places stress on surrounding structures and can lead to injury (Van Merkensteijn & Quin, 2015). Passive hip external rotation affects the overall turnout range of dancers, as their ROM and strength for hip external rotation are generally significantly greater than those of non-dancers (Gupta *et al.,* 2004). Compensated turnout is the difference between FTO and total passive hip external rotation ROM (Coplan, 2002; Champion & Chatfield, 2008) and is often referred to as “overturning” or “forced turnout” in the dance community (Van Merkensteijn & Quin, 2015). An increased CTO increases the risk of injury to the lower limbs (Coplan, 2002; Negus *et al*., 2005; Van Merkensteijn & Quin, 2015).

An association between gluteus medius weakness and the three main predictors of nontraumatic dance-related hip injury has been proposed, given that the function of this muscle as an internal and external hip rotator has an impact on turnout (Cheatham *et al*., 2015). Muscle weakness can lead to increased femoral internal rotation, placing the acetabulum in an incorrect position that may predispose the individual to ISH (Yen *et al*., 2015; Via *et al*., 2017). It is unclear why the gluteus medius becomes weak in this population, and the pathogenesis thereof is poorly understood (Via *et al*., 2017). A recent study by Kızıltoprak & Dinçer (2022) demonstrated that hip abductor muscle strength was not affected by the presence of SH in a group of pre-professional dancers (aged between 16 and 20 years), which might suggest that the gluteus medius' mobility function as an abductor is not impaired but rather its stability role during balance. Previous studies report a relationship between gluteus medius weakness and poor dynamic balance in the general population (Leavey *et al*., 2010; Norris & Trudelle-Jackson, 2011). In two studies, where balance training and gluteus medius muscle strengthening were implemented over a 6-week period, dynamic postural control significantly improved in groups of netball players and healthy, active college students, respectively. Similar to netball players, dancers rely on dynamic postural control; therefore, it is worth investigating balance and gluteus medius muscle strength in dancers with SH. No literature was found on the relationship between dynamic balance and SH, or how hip muscle strength relates to balance in dancers with SH. Considering that FTO, CTO and hip external rotation are predictors of lower limb injuries in dancers, it would be beneficial to assess gluteus medius muscle strength and dynamic balance in dancers with SH since both poor dynamic balance and hip muscle weakness are modifiable factors that could potentially be addressed to treat or to prevent SH.

PURPOSE OF RESEARCH

This study investigated hip muscle strength and dynamic balance in a population of recreational dancers with SH. The study aimed to describe dynamic balance, hip external rotation, and abductor muscle strength, as well as FTO, CTO, and ROM for hip external rotation, in dancers with SH; to identify any differences in these variables between the affected and unaffected sides; and to determine whether any relationships exist.

METHODOLOGY

Study design and setting

A descriptive cross-sectional study with an analytical component was conducted at selected multigenre dance schools in the northern suburbs of Cape Town, South Africa.

Study population and sampling

The population comprised nonprofessional adolescent and adult dancers engaging in ballet, modern and contemporary dance styles who attended the selected dance schools and who were diagnosed with extra-articular SH. The rationale for only including extra-articular SH was based on its common presentation and nontraumatic nature. Inclusion criteria were (1) nonprofessional or recreational dancers; (2) dancers who were aged between 15 years and 40 years (most common age range for SH injury (Cheatham *et al*., 2015); (3) dancers who were diagnosed with extra-articular SH based on the screening tests; and (4) dancers who had volunteered and consented to participate in the study. Dancers were excluded if they had (1) a current lower limb injury or injury in the last year; (2) vestibular and/or vision disturbances affecting balance; (3) known bony hip anomalies; (4) steroid injections and/or surgery to the hip in the last 2 years; (5) osteoarthritis, intra-articular pathology or muscular disease; (6) debilitating pain prohibiting test performance; (7) no confirmable extra-articular SH diagnosis using screening tests or if SH diagnosis was confirmed bilaterally, without clear indication of symptom variation (e.g. no symptoms); or (8) pregnancy (relaxin hormone relaxes ligaments and tendons and can affect test outcomes (Dehghan *et al*., 2013). The exclusion criteria were confirmed during the screening process.

In consultation with a biostatistician, a sample size of 38 was calculated to achieve precision of ±2% and a 95% interval. This was based on data from a previous study by Martinez *et al.* (2014) where the mean [82%, standard deviation (SD) 6.0] of the main variable, the Star Excursion Balance Test (SEBT), was used. Twenty dance schools out of 33 were randomly selected from a list of dance schools in the northern suburbs of Cape Town. The head teacher at each dance school was contacted, and the purpose of the study was explained. Permission to visit the dance school, to introduce and explain the study, and to invite the dancers to participate was obtained. Interested participants were given a screening questionnaire to complete, and eligible participants were invited for a physical assessment to confirm SH diagnosis. Participants with confirmed SH diagnoses then underwent further testing for study outcomes.

Recruitment commenced once most dance schools had resumed operation under the COVID-19 government guidelines at the time, and precautionary measures were implemented during data collection to mitigate COVID-19 transmission risk. Recruitment and data collection took place from March 2021 to July 2021.

Data collection and analysis

Participant demographics and the following outcomes were identified: pain, FTO, CTO, ROM for passive external hip rotation, hip abductor and hip external rotator muscle strength, and dynamic balance. Tests were collected in random order of limb side, starting with the tests in standing and then progressing to testing in supine on a plinth.

Screening measures

Screening questionnaire: A questionnaire originally designed by Winston *et al.* (2007) for assessing SH in a group of elite ballet dancers was adapted (permission granted) for this study. The customised questionnaire related specifically to nonprofessional dancers; the diagnostic ultrasound component was removed, and a demographic component was added. Questions included the level of dance, hours trained per week, symptoms related to SH, past injuries, and previous treatment or diagnosis.

Numeric pain rating scale (NPRS): Pain intensity was recorded on a scale measuring 0–10 (Haefeli & Elfering, 2006). This was included in the screening questionnaire, along with questions determining the location and frequency of hip pain. The NPRS correlates significantly with other pain assessment tools and is valid for use in adolescent and adult populations (Haefeli & Elfering, 2006; Ferreira-Valente *et al.*, 2011; Castarlenas *et al.*, 2017). Participants were categorised into four groups (always, sometimes, rarely, or never) based on the frequency of reported SH related pain. The NPRS was also used during the physical assessment when needed.

Screening tests for extra-articular SH: To test for ISH, participants were placed in the supine hip flexion, abduction, and external rotation (FABER) position. The hip was passively moved to extension, adduction and internal rotation to elicit the snap towards the end of the movement, which indicated a positive test (Yen *et al.*, 2015; Via *et al.*, 2017). For assessing ESH, participants were placed in the side-lying position with the test leg on top and in a neutral position (Yen *et al.*, 2015; Via *et al.*, 2017). If active hip flexion followed by passive extension produced the snap, the test was considered positive. If both hips were diagnosed with SH, the most painful limb (NPRS score) was considered the affected side.

Study outcomes

Dynamic balance

The Y-test, a modified version of the SEBT, was used to assess dynamic balance by measuring three reach directions (Linek *et al.*, 2017). The Y-test was easy to administer and was less time-consuming than the SEBT. This test showed good intra-rater reliability [intra-class correlation coefficient (ICC) 0.84–0.87] for the three reach directions, demonstrated test-retest reliability (ICC 0.89–0.93), and was a valid measure of dynamic balance (Plisky *et al.*, 2006; Schwiertz *et al.*, 2020). The participant stood with the toes of the weight-bearing foot in the centre of a Y-shape created by three lines of tape and was instructed to reach as far as possible in each direction (anterior, posteromedial and posterolateral) with the non-weight-bearing (working) foot. If any weight was placed on the working foot and/or if the participants lost their balance, they were required to redo the attempt. A measuring tape was used to capture the reach distance in metres in each direction (see Figure 1). For each reach direction and side (affected and unaffected), the average of three measurements was taken to increase reliability (Linek *et al.*, 2017). To account for the various leg lengths of the participants, the averages of the three reach distances were summed, divided by three times the participant's leg length, and multiplied by 100 (Linek *et al.*, 2017). This was presented as a percentage score, yielding a composite balance score for the affected and the unaffected sides. Leg lengths were measured in the supine position from the anterior superior iliac spine to the medial malleolus of the ankle (Martinez *et al.*, 2014).

Functional turnout, passive hip external rotation and compensated turnout

Functional turnout was measured as described by Negus *et al.* (2005). To the authors' knowledge, no standardised measure exists to measure turnout in dancers (Champion & Chatfield, 2008). The first position in dance, in which the lower limbs are externally rotated and the heels are together, was used. The participant stood on a piece of paper in the first position, and the outlines of both feet were traced. For each foot, a line was drawn from the centre of the heel through the second toe (see Figure 2). The angle between the heels was measured with a goniometer to obtain the FTO (Negus *et al.*, 2005).

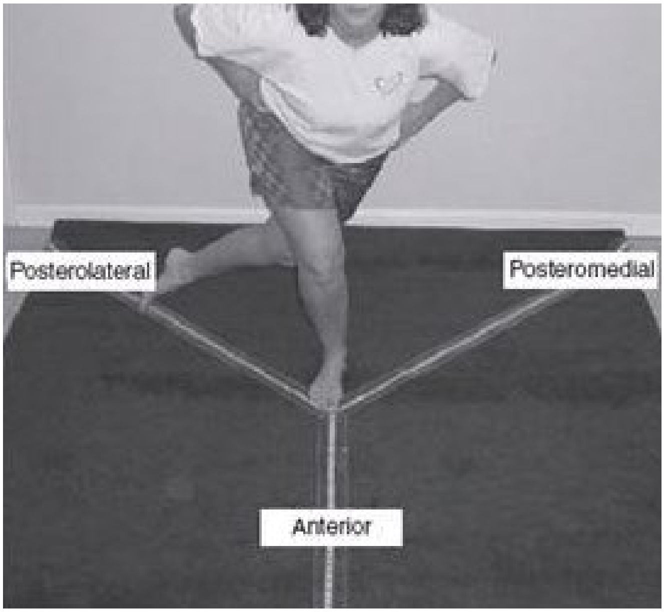


Figure 1. **DYNAMIC BALANCE TEST (Y-TEST).** The Y-test (modified SEBT) with reach directions labelled in reference to the right stance foot (Plisky *et al*., 2006)

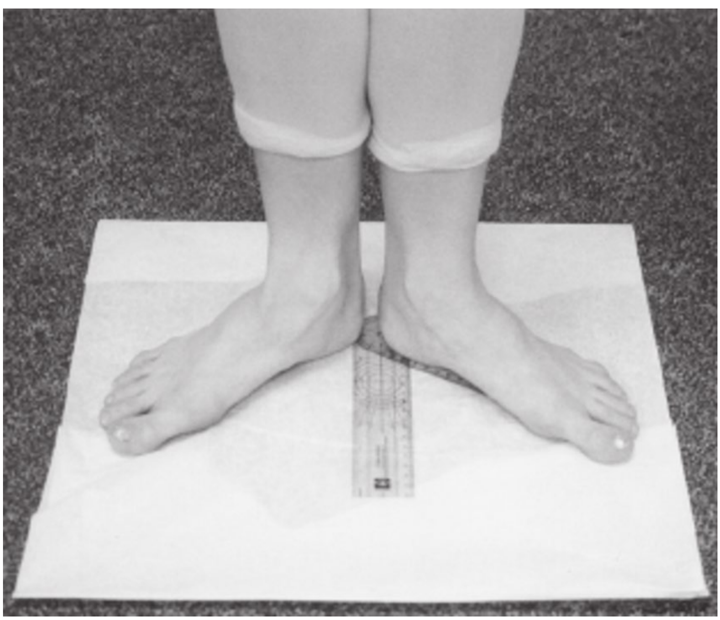


Figure 2. **FUNCTIONAL TURNOUT TEST.** Measuring functional turnout (Grossman, 2003)

Passive external hip rotation was measured in the prone position using a goniometer, with the knee flexed to 90 degrees, the contralateral hip abducted to 30 degrees and the pelvis stabilised (Martinez *et al.*, 2014). The stationary arm of the goniometer was aligned with the vertical line of the plinth, the goniometer axis was placed on the tibial tuberosity, and the mobile arm was placed along the tibia.

Compensated turnout was calculated by subtracting the summed value of the left and right passive external hip rotation from the value of FTO (Coplan, 2002).

Hip external rotation and abduction muscle strength

Muscle strength was measured in newtons (N) using a handheld dynamometer (Lafayette model 01165, USA) and the "make" test (sustained maximal isometric muscle contraction by the participant while the examiner holds the dynamometer stationary) (Thorborg *et al.*, 2010). The tests demonstrated good intra-rater reliability for hip abductor strength (ICC = 0.74) and hip external rotation (ICC = 0.99) when the best of four attempts was considered (Thorborg *et al.*, 2010). For the purposes of this study, the hip muscles were grouped together as external rotators or abductors. To test hip abductor strength, the participant was in a supine position (Thorborg *et al.*, 2010; Jacobsen *et al.*, 2012). To test hip external rotation strength, the participant was in a prone position with the knee flexed to 90 degrees. The participant was instructed to increase the effort gradually over two seconds and then hold the maximum effort for up to 5 seconds. For hip abductor strength and hip external rotation strength, the dynamometer was placed 0.05 m above the lateral and the medial malleoli, respectively. Four attempts were recorded, and the average of the three best recordings was taken.

All screening and measurement tests were performed by the first author (a qualified and registered physiotherapist with 7 years' postgraduate experience). See Figure 3 for a summary of the recruitment and data collection procedures.

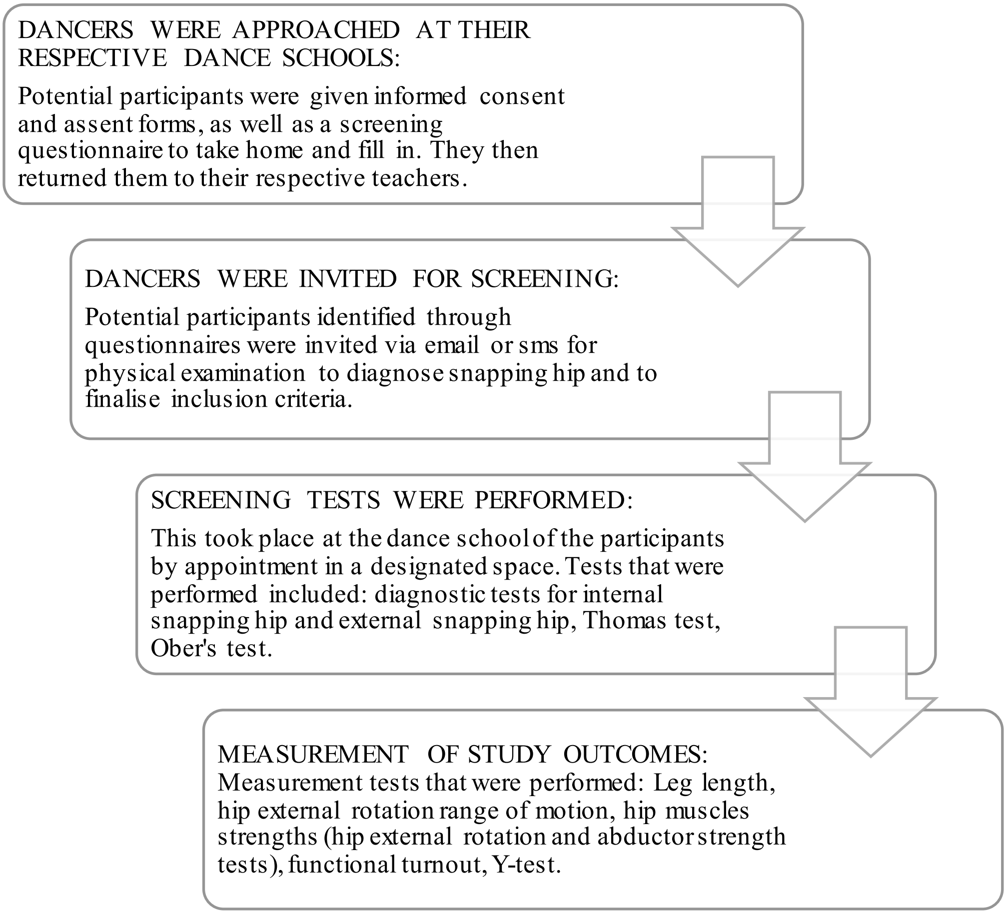


Figure 3. **DATA COLLECTION PROCEDURE**

Statistical analysis

Stata version 17 was used for the data analysis. Statistical significance was set at 5%. Participant characteristics were described using means, SDs and 95% confidence intervals (CIs) (normally distributed numerical data). Frequencies and percentages were reported for categorical data. Paired t-tests were used to compare the means of outcomes between the affected and unaffected sides. Mean age was compared across the four pain categories (always, sometimes, rarely, or never) using one-way analysis of variance (ANOVA). Pearson's correlation coefficients were calculated to determine whether any relationships existed between hip external rotation ROM and hip external rotation muscle strength; CTO and hip muscle strength (external rotators and abductors); dynamic balance and hip muscle strength (external rotators and abductors); and dynamic balance and CTO. Correlation coefficients of 0.2≤0.39 were considered weak; 0.4≤0.59 moderate; 0.6≤0.79 strong; and 0.8≤1.0 very strong (Mukaka, 2012).

Ethical considerations

Ethical approval was obtained from the Health Research Ethics Committee (HREC) of Stellenbosch University (S20/10/288). The study was conducted according to the Declaration of Helsinki (World Medical Association [WMA], 2013) and the Department of Health Guidelines for Good Clinical Practice (Department of Health, 2020). All parents and participants gave written informed consent and assent. A study ID code was allocated to each participant for confidentiality. Electronic files were digitally encrypted and password-protected, and hard copies were archived for a minimum of 5 years at the university.

RESULTS

Sample selection

Five of the 20 schools that were approached agreed to participate. Thirty-two potential participants completed the screening questionnaire, and 25 completed the physical assessment. Of the seven participants who were excluded, one declined the assessment, one was younger than 15 years, one withdrew due to COVID-19 exposure, and four did not present with snapping hip. Twenty-three participants were diagnosed with ISH and participated in the study.

Sample characteristics

All 23 participants were female, with a mean age of 22 years (SD 6.8; range 15–38 years). Of the 23 participants, nine (39%) were 18 years or younger. Fourteen participants (61%) danced for 1–3 hours per week, six participants (26%) for 3–6 hours, and three participants (13%) for more than 6 hours per week. Of the nine dancers who danced for three or more hours per week, six (67%) were younger than 18 years old. Nineteen participants (83%) reported pain, and four participants (17%) reported discomfort associated with the SH. The mean NPRS score (as reported for the previous week) was 2.1 (SD 2.2), while the mean NPRS for the highest reported pain ever experienced for the SH (no specific timeline or event) was 3.4 (SD 2.5). Thirteen participants (57%) had bilateral SH, of which ten reported no pain, two negligible (NPRS of 0.5), and one had a higher pain score (NPRS 5) on the unaffected side. According to Boonstra *et al.* (2016), a score of 5/10 or less is considered mild. Therefore, the less affected limb from the bilateral SH group were grouped with the unaffected side from the unilateral SH group. Nine participants (39%) reported that they had prior knowledge of the condition. Participant height and weight data were not collected. Out of 23 participants, 21 were right-sided dominant, one left dominant and one unknown. Other SH-related information gathered by the screening questionnaire is reported in Table 1.

Description of study outcomes and differences between affected and unaffected sides

The results for all study outcomes are reported in Table 2 according to affected and unaffected sides. There were no significant differences in the study outcomes between sides (p=0.28–0.70). Passive hip external rotation ROM and hip abductor strength were slightly greater for the affected side than the unaffected side. Hip external rotation strength was slightly stronger on the unaffected side than the affected side. There was also no significant difference between the two sides for any outcomes based on the age groups (adolescents vs. adults) ($p \geq 0.05$).

Table 1. **SAMPLE CHARACTERISTICS RELATED TO SNAPPING HIP**

Characteristic	**Description**	**Responses, n (%)**
Injuries 2 years ago (excl. the last year)	Reported lower limb injuries	15 (65.22)
Affected side	Right hip	7 (30.43)
	Left hip	3 (13.04)
	Both hips	13 (56.52)
Frequency of snap	> 5×/day	5 (21.74)
	1-5×/day	6 (26.09)
	> 1×/week	7 (30.43)
	< 1×/week	5 (21.74)
Frequency of pain when the hip snaps	Always	3 (13.04)
	Sometimes	8 (34.78)
	Rarely	8 (34.78)
	Never (reported discomfort)	4 (17.39)
Occurrence of pain (when)	During snap	12 (52.17)
	Before snap	7 (30.43)
	After snap	4 (17.39)
	After repeated snap	2 (8.70)
	N/A (no pain)	1 (4.35)
Snaps hip on purpose	Able to snap hip	11 (47.83)
Reason for snapping hip on purpose	To relieve pain	5 (21.74)
	To “free” the hip	7 (30.43)
	Out of habit	3 (13.04)
	To hear the noise	1 (4.35)
Stopped dancing due to pain	No	18 (78.26)
	Yes, once	0 (0.00)
	Rarely	3 (13.04)
	Sometimes	2 (8.70)
	Often	0 (0.00)
Took days off from dance	Between 30-180 days	3 (13.04)
What relieved pain	Rest	7 (30.43)
	Physiotherapy	3 (13.04)
	Heat/ice	2 (8.70)
	Stretching	8 (34.78)
	Strengthening	1 (4.35)
	Massage	3 (13.04)
	Chiropractor	1 (4.35)
	N/A (not debilitating enough)	8 (34.78)

N/A=not applicable

Table 2. **DESCRIPTIVE STATISTICS AND COMPARISONS FOR ALL STUDY OUTCOMES**

Variable	**Affected, (*n*=23)**		**Unaffected, (*n*=23)**		**Mean difference[a]**	**95%CI**	***p* value**
	Mean (SD)	CI	Mean (SD)	CI			
ROM HER (degrees)	40.21 (8.52)	36.53, 43.90	39.30 (8.04)	35.82, 42.78	0.91	-2.05, 3.88	0.53
HER STR (N)	85.73 (17.61)	78.12, 93.35	87.74 (15.99)	80.83, 94.66	-2.01	-8.00, 3.98	0.49
ABD STR (N)	78.94 (16.78)	71.69, 86.19	76.11 (18.53)	68.11, 84.13	2.83	-2.49, 8.14	0.28
COMP (%)	87.53 (5.49)	85.16, 89.90	87.27 (4.84)	85.18, 89.37	0.26	-1.11, 1.62	0.70
FTO (degrees)	117.73 (14.14)					N/A	
CTO (degrees)	38.21 (12.16)					N/A	

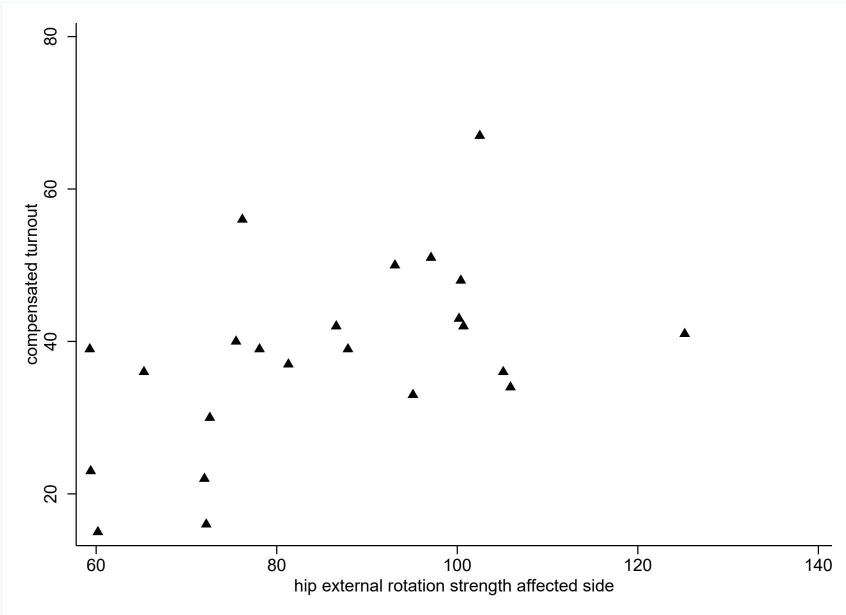
ABD STR=hip abduction muscle strength CI=confidence interval COMP=composite reach distance for balance CTO=compensated turnout FTO=functional turnout HER STR=hip external rotation muscle strength N=Newtons *n*=number of participants ROM HER=range of motion for hip external rotation SD=standard deviation.
[a] Differences calculated using a paired t-test.

Pain category according to age

The mean ages of participants who reported to "always" (*n*=3), "sometimes" (*n*=8), "rarely" (*n*=8) or "never" (*n*=4) experience pain were 19.7 years (SD 2.5), 19.6 years (SD 4.2), 24.8 years (SD 7.9) and 21.8 years (SD 7.7), respectively. There were no statistically significant differences between groups (p=0.42) and thus, no post hoc tests were conducted.

Relationship between study outcomes

One significant positive, moderate correlation was noted between HER muscle strength on the affected side and CTO (r=0.51, p=0.01) (Figure 3A). Other noteworthy moderate correlations where all in a positive direction and although not significant, were between CTO and hip abduction muscle strength on the unaffected side (r=37) (Figure 4B) and between dynamic balance and HER muscle strength (r=0.37) and hip abduction muscle strength (r=0.40) on the unaffected side (Figures 5A and B).



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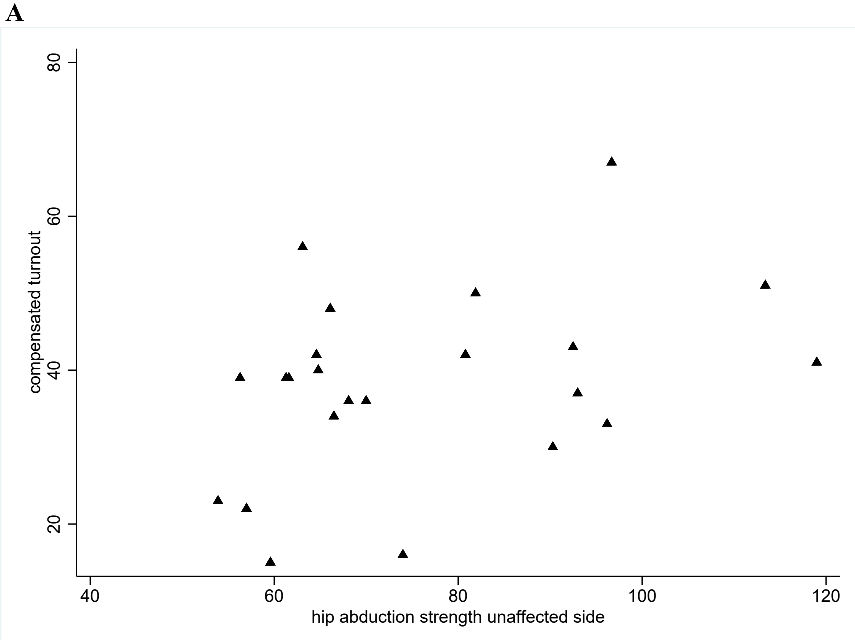

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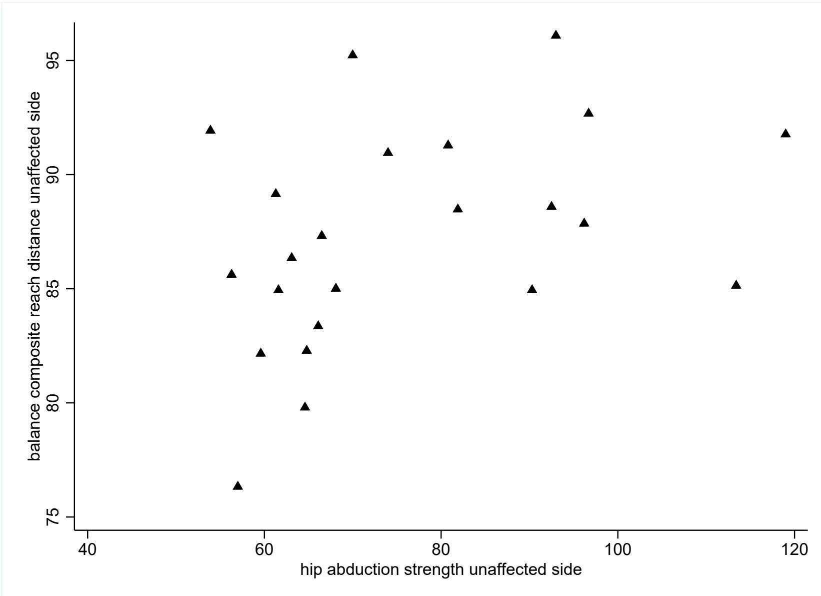
Figure 4. **SCATTER PLOTS OF RELATIONSHIPS BETWEEN (A) HIP EXTERNAL ROTATION STRENGTH AFFECTED SIDE AND COMPENSATED TURNOUT AND (B) HIP ABDUCTION STRENGTH UNAFFECTED SIDE AND COMPENSATED TURNOUT**



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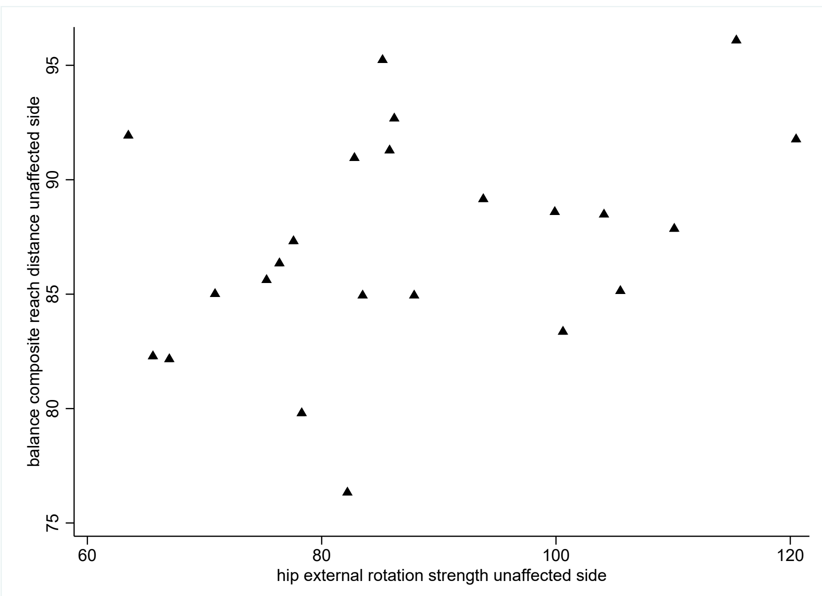

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Figure 5. **SCATTER PLOTS OF RELATIONSHIPS BETWEEN (A) HIP ABDUCTION STRENGTH UNAFFECTED SIDE AND COMPOSITE BALANCE SCORE UNAFFECTED SIDE AND (B) HIP EXTERNAL ROTATION MUSCLE STRENGTH UNAFFECTED SIDE AND COMPOSITE BALANCE SCORE UNAFFECTED SIDE**

DISCUSSION

This study investigated selected outcomes in dancers with SH to determine relationships between potential modifiable factors such as dynamic balance and hip muscle strength in addition to the common injury predictors FTO, CTO and hip external rotation ROM. Although the results indicated no significant differences in the study outcomes between the affected and unaffected limbs, hip external rotation muscle strength demonstrated a significant positive correlation with CTO for the affected limb.

Description of demographics and study outcomes

The sample characteristics were generally aligned to those commonly reported in the literature. All participants were young females, with more than half of them presenting with bilateral SH (Winston *et al*., 2007; Laible *et al*., 2013). Winston *et al*. (2007) found that younger female dancers were more at risk of developing SH and presenting with bilateral SH than the general population. Furthermore, the findings demonstrated an apparent low level of awareness among dancers regarding SH in addition to non-health-seeking behaviours (e.g. continued dancing) despite the prevalence of the condition – a juxtaposition also reported in the literature (Winston *et al*., 2007; Jacobs *et al*., 2017). This is concerning because it may lead to future reinjury given the relationship between training hours and injury history (Kenny *et al*., 2021) and the observed tendency of dancers to train and perform through pain.

Van Merkensteijn and Quin (2015) report similar scores for CTO and FTO in a cohort of university-level modern dancers aged between 19 years and 23 years and with various dance-related injuries. Two other studies investigated CTO and FTO in ballet dancers with injuries of the lower extremities (Coplan, 2002; Negus *et al*., 2005). The FTO and the CTO scores varied considerably in these two studies, which included pre-professional and professional dancers, respectively. It appears that CTO and FTO differ depending on the skill level of the dancer and according to the type of lower limb injury and may not necessarily be associated with SH. Future research on dancers with SH should provide comprehensive information regarding the injury profiles of the participants.

The dynamic balance scores found in this study were comparable with those reported by Martinez *et al*. (2014) in their study of two groups of healthy ballet dancers (recreational and professional) (80% vs. 87% in the current study). In the study of Martinez *et al*. (2014), recreational dancers had better dynamic balance than the professional group, although the finding was statistically insignificant. The authors reasoned that recreational dancers had more opportunities to rest between training sessions and had more diverse dance classes than professional dancers. However, comparisons should be interpreted with caution due to the differences in sample characteristics and the methods of balance testing. Given the lack of literature on dynamic balance in dancers with SH, it is difficult to interpret the implications of the dynamic balance findings of the current study. More research is needed to determine why dynamic balance may differ between different groups of dancers and the implications (if any) of such differences, including proper descriptions of injury profiles and level of dance, as these seem to influence dynamic balance.

As with dynamic balance, similarities were found with other studies when looking at hip external rotation ROM in dancers (Champion & Chatfield, 2008; Martinez *et al*., 2014). However, these studies examined healthy dancers without SH or injury, which made it challenging to draw meaningful conclusions about the current study's findings regarding hip ROM. Additional studies with larger sample sizes and including dancers with SH are needed.

This study measured hip muscle strength in newtons (N), whereas other studies converted their findings to newtons per kilogram (N/kg), which complicates comparisons. Thorborg *et al.* (2010) tested the hip muscle strength of nine healthy non-dancers using a handheld dynamometer, measuring in newtons. The results showed a greater force for both the hip external rotation muscle strength and the hip abduction muscle strength than that of the current study. Hip abduction strength was also greater in the healthy individuals in the study of Thorborg *et al*. (2010), which is contrary to this study's dancers with SH who presented with greater hip external rotation muscle strength (vs. hip abduction strength). Hip external rotation strength on the affected side was less than the unaffected side (although insignificant), underpinning what is already known regarding muscle strength and SH, especially ISH (Yen *et al*., 2015; Via *et al*., 2017).

Differences in study outcomes between the affected and the unaffected sides

No significant differences were found between the affected and the unaffected sides for any study outcomes. A trend was noted that generally, the affected sides demonstrated better values than the unaffected sides, except for hip external rotation strength. This finding correlates with other literature regarding the pathogenesis of ISH (Yen *et al*., 2015; Via *et al*., 2017) where weakness of the gluteus medius (contributing to external rotation of the hip) is one of the contributing factors of SH. The lack of significant differences between the affected and the unaffected sides could be due to the severity of ISH. Kızıltoprak and Dinçer (2022) also found that hip abduction strength was not different between the hips with SH and those without. The NPRS scores in this study were generally low, and the pain scores of the less severe side in bilateral SH were not explored separately. Although there were three participants with pain in both hips, the less severe side was still considered the unaffected side in this study, as the pain on that side was mild (Boonstra, *et al*., 2016). Furthermore, dancers also had time to recover during the COVID-19 period when activity and time spent in classes were reduced. Finally, determining statistically significant differences between affected and unaffected sides is more challenging in a small sample (Peterson & Foley, 2021).

Relationships between study outcomes

A significant moderate positive correlation was found between CTO and hip external rotation muscle strength on the affected side. This may be due to the hip external rotation strength on the affected side being weaker on average than the unaffected side in this sample, with the decreased strength potentially limiting the overall FTO a dancer can achieve. No studies that considered the relationship between CTO and hip external rotation muscle strength were found. However, it is suggested that poor "turnout" control leads to compensatory patterns, meaning that adequate muscle strength is needed for proper turnout (Van Merkensteijn & Quin, 2015). A study by Sherman *et al.* (2014) evaluated whether the difference between passive and active turnout can be reduced with a turnout conditioning programme (targeting deep hip external rotation muscle strength) in young dancers. The authors found a significant improvement in the active turnout (which relates to FTO) and a reduction in the difference between active and passive turnout. These findings suggest that hip external rotation muscle strength plays an important role in the FTO of dancers and can directly influence the CTO.

Compensated turnout and hip abduction muscle strength on the unaffected side also showed a trend towards a positive relationship, although this finding was not statistically significant. The hip abductors on the unaffected side were weaker than those on the affected side. This could concur with the previous discussion on the nature of the relationship between CTO and hip external rotation strength on the affected side, where a decrease in hip abductor strength on the unaffected side could potentially decrease CTO and FTO, and vice versa. It is important to note that the hip abductors also play a role in external rotation of the hip (Cheatham *et al.*, 2015). The weaker muscle, regardless of which side, seems to be related to CTO.

Dynamic balance was positively correlated with both hip external rotation strength and abduction strength on the unaffected side, although it was not statistically significant. Good dynamic balance has been linked to a strong gluteus medius muscle in the general healthy population (Leavey *et al.*, 2010; Norris & Trudelle-Jackson, 2011). On the affected side, the relationship between the balance and muscle strength was less strong and was potentially influenced by pain severity on the side with SH (Van Wilgen *et al.*, 2003). It should be noted that during balance testing on the affected side, the gluteus medius muscle has a stabilisation function and not a mobility function (in this study muscle strength tested the mobility function) (Norris & Trudelle-Jackson, 2011; Cheatham *et al.*, 2015).

Pain

In the current study, most dancers (83%) reported pain associated with their SH, and this was in line with the study of Laible *et al.* (2013) in which most dancers had pain but with low pain scores. This could be due to these dancers spending less time dancing than professionals, decreasing the chances of developing painful SH. In a case report of three elite athletes (two football players and one soccer player), a high level of pain was brought on by repetitive extreme hip flexion movements, which led these athletes to seek treatment for their ISH (Wahl *et al.*, 2004). This is in contrast with the group of professional ballet dancers who reported that their SH was not problematic and although they experienced varying degrees of pain and discomfort, it did not stop them from dancing. The professional ballet dancers may have had a higher pain threshold than the elite athletes (Winston *et al.*, 2007), and they often ignore their injuries and symptoms to excel in their careers (Jacobs *et al.*, 2017). The participants of this study may also have had a higher pain threshold. There is a lack of research investigating the development of painful SH, and cases are generally reported only when they are symptomatic (Wahl *et al.*, 2004; Laible *et al.*, 2013). In a study with a group of pre-professional ballet dancers with SH there was a negative correlation between the Copenhagen Hip and Groin Outcome score (HAGOS) and snapping intensity (Kızıltoprak & Dinçer, 2022). This meant that the lower their score (i.e., reporting higher pain levels, more severe symptoms, lower physical function in daily life and sport, lower participation in physical activities, and lower quality of life) the greater their symptoms.

The influence of age on pain was explored in the current study and the findings indicated that the younger participants had more pain than the older participants. In this study, the younger group (<20 years old) danced at least 3 or more hours per week than the older group (>20 years old) who danced between 1 hour and 3 hours per week. Young dancers tend to train more regularly than older dancers, as they are still learning the art and mastering the techniques. This leaves more room for training errors and poor technique in young dancers, which may lead to injury and possibly explain the higher level of pain. Regular training in the wrong form or with poor technique could lead to small biomechanical changes over time (Coplan, 2002). A recent systematic review by Migdou *et al*. (2024) found that increased training loads and hyperactivity also contributed to the development of hip injuries. Compensated turnout has been identified as a training error that predisposes the dancer to the risk of injury (Van Merkensteijn & Quin, 2015).

Limitations and recommendations

This study has limitations that must be considered when interpreting the results. One major limitation is the small sample size, as the precision of results relied on achieving a specific sample size. This could have led to imprecise estimates and the absence of statistical significance in comparisons. The desired sample size was not reached because of several reasons, the main one being the COVID-19 lockdowns. Furthermore, because of the pragmatics of a master's project, the sample consisted of only women (aged 15–40 years) from the northern suburbs of Cape Town. The results can, therefore, not be generalised to all dancers. Another limitation was combining unilateral and bilateral SH, as SH without pain symptoms could potentially have influenced the study outcomes, although most of the participants with bilateral SH had no or mild pain. A larger, more diverse sample should be included in future studies so that subgroups based on age and unilateral versus bilateral SH could be explored in terms of its impact on pain, muscle strength and balance. Although the cross-sectional design described the study outcomes at a particular time, longitudinal studies would yield more valuable information regarding the development of risk factors, causality, and the influence of pain on SH. Including participants with a higher pain score on the NPRS could provide more insight into the influence of pain on the relationships between the study outcomes. Instrumented motion analysis could be included in future studies to gain insight into muscle activity during balance testing, and dynamic muscle strength testing should be incorporated. Including the muscle strength testing of the hip adductor group would also provide additional insight as this muscle group contributes to HER ROM (Byrne *et al*., 2010). Outcomes such as muscle strength should be assessed using standardised units to enable comparisons across studies and populations.

PRACTICAL APPLICATIONS

The results regarding the relationships between dynamic balance and hip muscle strength were inconclusive, however, the findings highlight the importance of screening a combination of measures. Dancers with SH should be screened for CTO because of the significant relationship that CTO has with hip external rotation strength on the affected side. However, screening should be done bilaterally because of the lack of differences found between sides. Moreover, CTO and hip external rotation muscle strength should be measured, and imbalances should be addressed as a potential management strategy. A general lack of knowledge regarding SH was noted among the dancers. This could be addressed by educating dancers regarding injury prevention and enabling them to seek help when needed. More studies are needed to identify potential rehabilitation strategies.

CONCLUSION

The findings of this study indicate that dancers with SH may not necessarily have poorer balance than healthy dancers. However, CTO and hip external rotation muscle strength on the affected side demonstrated a moderately positive and significant correlation, indicating that addressing the muscle weakness may improve CTO and reduce injury risk. Further investigation is, however, needed. There are limited studies on dancers with SH or on SH in general, making suggestions for rehabilitation strategies difficult. Future studies are needed to provide more information on the development of the condition and how pain may have an impact on balance.

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Conflict of interests

None to declare.

Authors' contributions

All the authors were responsible for the conceptualisation of the study; Ms RA Lategan collected the data and wrote the first draft of the article. All the authors contributed to the final written article.

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