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The effects of acute experimental hip muscle pain on dynamic single-limb balance performance in healthy middle-aged adults

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RESEARCH HIGHLIGHTS:

- Acute hip muscle pain alone does not alter dynamic balance in middle-aged adults
- Balance performance is improved with task repetition irrespective of pain presence
- Factors other than pain may underpin poor balance in people with hip pathologies

ABSTRACT

Middle-aged adults with painful hip conditions show balance impairments that are consistent with an increased risk of falls. Pathological changes at the hip, accompanied by pain, may accelerate pre-existing age-related balance deficits present in midlife. To consider the influence of pain alone, we investigated the effects of acute experimental hip muscle pain on dynamic single-limb balance in middle-aged adults. Thirty-four healthy adults aged 40-60 years formed two groups (*Group-1:* n=16; *Group-2*: n=18). Participants performed four tasks: Reactive Sideways Stepping (ReactSide); Star Excursion Balance Test (SEBT); Step Test; Single-Limb Squat; before and after an injection of hypertonic saline into the right gluteus medius muscle (*Group-1*) or ~5 minutes rest (*Group-2*). Balance measures included the range and standard deviation of centre of pressure (CoP) movement in mediolateral and anterior-posterior directions, and CoP total path velocity (ReactSide, Squat); reach distance (SEBT); and number of completed steps (Step Test). Data were assessed using three-way analysis of variance. Motor outcomes were altered during the second repetition of tasks irrespective of exposure to experimental hip muscle pain or rest, with reduced SEBT anterior reach (-1.2±4.1 cm, P=0.027); greater step number during Step Test (1.5±1.7 steps, P<0.001); and slower CoP velocity during Single-Limb Squat (-4.9±9.4 $mm.s^{-1}$, P=0.024). Factors other than the presence of pain may play a greater role in balance impairments in middle-aged adults with hip pathologies.

Key Words: Hip muscle pain; Hypertonic saline; Balance performance; Middle-aged adults

INTRODUCTION

Age-related balance impairments are observed in adults from as early as their fourth decade [1]. For example, healthy women aged 40-80 years have reduced single-limb balance control during quiet standing [2, 3], lower limb reaching [4], and stepping [3] tasks, compared to younger adults. Decreased lower limb muscle strength [5, 6], reduced joint range of motion [6, 7], altered sensorimotor function [8, 9], and declining physical activity levels [6, 7, 10], may all contribute to balance deficits in midlife.

At the hip, greater trochanteric pain syndrome, chondropathy, and osteoarthritis are common sources of hip pain. Chronic pain is of particular concern in middle-aged adults, as it appears to be a strong risk factor for falls in later life [11, 12]. Consistent with an increased risk of falling, dynamic single-limb balance is impaired in adults who show early signs of hip joint degeneration and report mild pain [13]. Further, the presence of hip osteoarthritis is associated with delayed postural adjustments prior to rapid sideways stepping [14], and impaired recovery of balance following perturbation [15]. Therefore, the presence of painful musculoskeletal disease or injury could accelerate pre-existing age-related balance deficits.

Pain is a modifiable patient-reported outcome with appropriate management. Greater understanding of how hip muscle pain alone, without the presence of pathology, can affect balance in middle-aged adults may inform the development of more effective strategies to manage balance problems in this population. Therefore, the aim of this study was to investigate the effects of hip muscle pain on dynamic balance in healthy middle-aged adults. We hypothesised that hip pain would lead to a deterioration of motor performance, that is, greater centre of pressure (CoP) movement during reactive side-stepping and single-limb squat tasks; reduced reach distance during the Star Excursion Balance Test (SEBT) and; fewer steps taken during the Step Test; relative to a no pain (control) condition. To isolate the effect of nociceptive stimulation from structural impairments, pain was induced experimentally by injection of hypertonic saline. At the hip, injections of hypertonic saline into gluteus medius have led to patterns of referred pain, regional deep tissue hyperalgesia, and pain provocation test responses, similar to those observed in hip pathologies [16]. We used a within-subject repeated measures design with two groups. Group-1 performed balance tasks before and after induced hip pain. Group-2 performed the tasks twice, with no pain. This design also allowed us to determine whether performance of novel motor tasks improves with repetition in middle-aged adults. We hypothesised that performance would improve in Group-2 (consistent with short-term adaptions in motor performance with repetition [17]), but that the presence of pain would be associated with worse performance in Group-1.

METHODS

Participants

Thirty-four healthy adults aged 40-60 years, were included in the study. Of these, 16 adults (11 women, 5 men; age 50.5±3.4 years; height 1.70±0.09m; weight 71.1±16.6kg) formed Group-1; and 18 adults (16 women, 2 men; age 51.6±4.6 years; height 1.67±0.08m; weight 63.6±12.0kg) formed Group-2. Group allocation was based on the participant’s willingness to receive an injection of hypertonic saline into their hip muscle and experience acute pain.

Exclusion criteria for both groups included current back or lower limb injuries or disease including pain; symptomatic hip or knee osteoarthritis; hip surgery; neurological conditions or previous stroke, sensory conditions known to alter balance (e.g. peripheral neuropathy); current use of pain medication or; inability to read/speak English. The study was approved by the Institutional Medical Research Ethics Committee (#2004000654). All procedures conformed to the Declaration of Helsinki. Written informed consent was obtained from all participants.

Design

Group-1 and Group-2 refer to the *Pain* and *Control* portions of this study, respectively. The protocols do not differ between Groups (except for the inclusion of a pain stimulus in Group-1). All participants conducted two blocks of testing, one before (Block-1) and one after (Block-2) the administration of acute pain (Group-1) or ~5 minutes rest (Group-2). The balance tasks included: Reactive Sideways Stepping (ReactSide); SEBT; Step Test; and Single-Limb Squats.

Equipment

Force data were obtained using two Kistler force platforms (Model 9296AA, Kistler, Alton, UK), sampled at 100Hz (Power1401 Data Acquisition System, Cambridge Electronic Design, UK) and low-pass filtered (20 Hz, 4th order Butterworth filter) off-line. An electrogoniometer (Twin Axis SG150, Biometrics Ltd., Newport, UK) was attached laterally over each knee joint, and used to measure knee angle during the squat. Data were sampled at 40Hz (DataLINK DLK900, Biometrics Ltd., Newport, UK). All data were collected using Spike 2 software (Cambridge Electronic Design, UK).

Balance Tasks

Participants were barefoot, with their eyes open and arms folded across their chest for all tasks. Prior to data collection, the investigator demonstrated each task, and participants performed 1-2 practice trials to facilitate familiarity with the procedures. For each task, the initial test leg was randomised. During Block-2, fewer trials were performed, in an attempt to complete all tasks before the cessation of pain (in Group-1, and for consistency, the number of repeats were matched in Group-2). For all tasks, balance measures were averaged across repetitions.

Reactive Sideways Stepping

Participants adopted a double-limb standing position, with one foot on each force platform, and their bodyweight evenly distributed between both legs. Taped lines were placed 10cm and 20cm lateral to the fifth metatarsal head of each foot [14]. In response to a verbal cue, participants stepped ~15cm sideways (to place their foot between the taped lines), as quickly as possible. The final position was maintained for ~3s, before returning to the starting position (Figure 1). Participants completed 20 trials (10 per leg), randomly presented. Approximately 10s was given between trials to allow for repositioning and rest. During Block-2, participants performed 5 trials per leg.

Star Excursion Balance Test

An 8-point star (each point set at 45°) was taped on the floor [18]. Participants began with the heel of their test leg at the centre of the star. Participants were instructed to "*Reach as far as possible along the line, without moving your standing foot. Keep the* *heel of your standing foot down. When touching the line with your reaching foot, try not to step or place all your weight down: lightly touch the ground then return to the starting position*." Participants performed three reaches along the anterior, medial and posteromedial lines. A 10s rest period was provided between repetitions. Tests were discarded and repeated if a participant raised the heel of their test leg off the ground, lost their balance, or bore weight through their reaching leg. The distance reached in each direction, per repetition, was measured. During Block-2, participants performed 1 reach per leg in all three directions.

Step Test

Whilst in a comfortable, double-limb standing position, a taped line was placed horizontally, in front of the most distal aspect of the participant's hallux. A 15cm high step (80cm width x 60cm depth) was placed 5cm in front of the taped line. Participants were instructed to "*Place your full foot on and off the step as many times as possible in 15s, keeping your other foot on the force platform*." [19]. The Step Test was performed three times on each leg, with a 5s rest period between trials. During Block-2, the Step Test was performed once on each leg. The number of completed steps performed in 15s was recorded.

Single-Limb Squat

An electrogoniometer was taped to the lateral aspect of each leg, across the knee joint. Thereafter, a plinth was placed directly behind the participant, with the height adjusted so that upon reaching an angle of 60° knee flexion, the participants' buttocks lightly touched the plinth [13, 20]. Participants stood with their test leg on a force platform, and were instructed to *'squat down until your buttocks lightly touch* *the bed behind, then return to the starting position and repeat 3 times in time with the count'* (Figure 2). For each leg, three sets of three repetitions were performed at a cadence of 3s lowering and 3s rising [13, 20]. A 30s rest period was provided between sets. For Block-2, all participants performed one set of three repetitions per leg. Notably, despite training and auditory feedback, this task was difficult for many participants to perform at the cadence intended (range, 10.8-20.7s). In order to match the maximum number of participants between groups, trials were discarded for any participant who performed the squat in less than 14.5s or greater than 18s. This allowed a comparison of 8 participants for each group who performed the task with similar cadence (mean cadence of those included was 16.2±0.8s).

Conditions

Group-1, Experimental Pain

Participants received a single bolus injection of hypertonic saline (1ml, 5%NaCl) into their right gluteus medius muscle, ~2cm distal to the mid-point between the anterior and posterior superior iliac spines. The accuracy of the location and depth of the injection was confirmed using ultrasound (12 MHz, Logic e, GE Healthcare, Australia). Saline was delivered using a 25Gx25mm needle. An 11-point numerical rating scale (0=no pain; 10=worst imaginable pain), was used to rate pain intensity during Block-2. Data collection commenced when the pain was reported as >2/10 [20]. If pain intensity was <2/10 prior to completion of all balance tasks, a second injection (1ml, 7%NaCl) was delivered ~1cm from the initial injection site (n=7, required a second injection).

Size of pain area was reported using a series of 10 circles ranging from 1cm-10cm in diameter. Participants selected the circle size that best represented their area of pain local to the injection site. Pain intensity and area were assessed prior to, mid-way through, and upon completion of each balance task. Scores were averaged to generate one score per task. At the end of all test procedures, participants reported their region of pain on a standardised 10cm body chart and completed the short-form McGill Pain Questionnaire [21].

Group-2, Rest

Instead of receiving a hypertonic saline injection, participants were asked to lie supine on a plinth for ~5minutes. This rest period was synonymous with the length of time participants in Group-1 were lying whilst receiving their injection. The purpose of Group-2 was to verify whether any alterations observed in balance in Group-1 could be attributed to the effect of pain, rather than short-term adaptation to motor performance with repetitions. Importantly, some prefer to use an isotonic saline injection as a control (rather than rest); however, such an injection also causes some discomfort, particularly when the needle is inserted into deep muscles. It was decided for the purposes of this study, that Group-2 (control) should not experience any hip pain or discomfort.

Data Analysis

Balance data were processed using Matlab (The Mathworks, Nathick, USA). Balance measures for the ReactSide and Squat tasks were CoP total path velocity (higher values indicating more rapid and potentially unstable movement), range (higher values indicating greater sway) and standard deviation (SD) (higher values indicative of greater exploratory or less controlled behaviour) of movement in the mediolateral (ML Range; MLSD) and anterior-posterior (AP Range; APSD) directions [13, 20]. Data were analysed from the start of the first repetition to the end of the third repetition of each squat movement. For ReactSide, CoP data for the supporting leg were analysed from “foot off” to “foot on” (visually detected) of the stepping leg force plate, to capture the period of unilateral standing [14].

Statistical Analysis

SPSS version 20.0 (SPSS Inc, Chicago, IL 60606, USA) was used for statistical analyses. Data was assessed for normality and homogeneity. Independent samples t-tests were used to explore any differences in demographic characteristics between-groups. A three-way analysis of variance (ANOVA) was used to assess differences in balance performance with ‘Group’ (Group-1; Group-2) as a between-subject factor, and ‘Condition’ (Pre-Condition; Post-Condition) and ‘Leg’ (Right/painful; Left/non-painful) as within-subject factors. Where a significant interaction was observed, Fisher’s Least Significant Difference post-hoc analyses were performed. Data are presented as mean±SD; statistical significance was set to $P<0.05$.

RESULTS

Participants

The groups did not differ in age ($P=0.455$), height ($P=0.298$), or weight ($P=0.140$).

Pain

Pain intensity and area across all tasks was 3.4±1.0/10 and 5.1±2.2cm^2, respectively. Referred pain was reported at the right lateral (n=1) and right medial (n=1) thigh. Pain was most commonly described as “throbbing” (n=6), “annoying” (n=4), “aching” (n=4) and “pressing” (n=4).

ReactSide

There was a significant main effect of Group for ML range (F(1,30)=4.550, *P*=0.041) and MLSD (F(1,30)=4.430, *P*=0.044), indicating between-group differences of 10.3±22.1mm and 3.2±6.9mm respectively, with less lateral sway in Group-1, regardless of Condition or Leg. There were no other main effects (all *P*>0.067) or interactions (all *P*>0.060) (Table 1).

SEBT

There was a significant main effect of Condition (F(1,31)=5.438, *P*=0.026) for anterior reach, which reduced by 1.2±4.1cm from pre- to post-condition. For medial reach, there was a significant main effect of Leg (F(1,31)=5.567, *P*=0.025), with greater distance achieved in the left (75.7±9.5 cm) compared to right (74.4±8.8 cm) leg. Significant Group effects were observed for anterior (F(1,31)=8.869, P=0.006) and medial (F(1,31)=4.350, *P*=0.045) reach, with Group-2 reaching further. No other main effects (all *P* values >0.138) or interactions (all *P* values >0.202) were observed (Table 1).

Step Test

There was a significant main effect of Condition (F(1,32)=33.319, *P*<0.001), with 1.5±1.7 more steps taken in Block-2, irrespective of Group and Leg. No main effect of Leg nor significant interactions (all *P* values >0.249) were observed (Table 1).

Single-Limb Squat

Fewer participants from either Group were able to complete the squat task well (i.e. unable to keep appropriate pace with the metronome). A post-hoc decision was made to include 8 of 16 participants in Group-1 and 8 of 18 participants in Group-2 who completed the squat task between 14.5-18s, without needing to 'touch down' with their raised foot. There was a significant main effect of Condition ($F(1,14)=6.382$, $P=0.024$) on velocity, with slower CoP movement (-4.9 ± 9.4mm.s^{-1}) during Block-2 irrespective of Group. No other main effects (both *P* values >0.061), or interactions (all *P* values >0.191) were observed (Table 1).

DISCUSSION

This study provides evidence that acute hip muscle pain alone, in middle-aged adults without lower limb pathology, does not alter dynamic single-limb balance. Rather, we show changes, argued to be short-term improvements in motor performance, with task repetition, irrespective of pain presence (Figure 3). Whilst our data also show a Group difference in three measures, specifically, less lateral sway (ReactSide), anterior and medial reach (SEBT) in Group-1 (pain) than Group-2 (rest) (Figure 3), no Group*Condition interactions were noted. Our findings indicate that factors, other than local hip pain may play a greater role in balance impairments observed in middle-aged adults with painful musculoskeletal conditions. Our findings are clinically important as early identification, and management, of individuals prone to balance deficits in midlife is vital, to prevent acceleration of functional decline, and reduce the risk of falling [22].

ML range and MLSD were significantly less in Group-1 than Group-2 during the ReactSide task. Reduced CoP movement is traditionally interpreted to suggest better balance. This is a notable finding, as measures of ML CoP movement are considered to be significant predictors of falls [23]. However, neither group showed a change in this measure with either pain or rest.

A significant main effect of Group was observed for anterior and medial reach distance, with Group-2 reaching further, however, this Group difference did not influence the overall effect of Condition on anterior reach distance. The reduction in SEBT anterior reach distance was observed during the second session irrespective of whether participants were exposed to experimental hip muscle pain or rest. Whilst this finding was statistically significant, it may not represent a true deterioration in SEBT performance. Munro and Herrington [24] reported a 6-8% change is needed to be confident that a true change in performance has occurred. Our data indicates a 1.8±5.3% reduction in anterior reach between-conditions, which is unlikely to be clinically meaningful. We also observed a significant effect of Leg on medial reach distance, indicating participants reached further with their left leg, which may reflect leg dominance [25].

Our study identified bilateral improvements in Step Test performance during the second condition, irrespective of Condition. This finding concurs with those of Bennell and Hinman [26] who reported no significant change in the number of steps taken when pain was induced at the medial infrapatellar fat compared to their control trial in healthy adults (aged 55.5±4.1 years). Together our results provide evidence of an improvement with task repetition, but no influence of acute pain on this measure.

CoP velocity was reduced in both groups when performing single-limb squats during the second condition. This finding may suggest that over time, the squat movement was performed in a more controlled manner, due to task familiarity. Relative to our work in healthy young adults [20], participants in this study showed greater amplitude and velocity of CoP movement during the squat, irrespective of condition, potentially highlighting age-related deterioration in balance.

There are several study limitations. First, consistent with Bryant et al [27] where >50% of middle-aged adults were unable to complete three trials of single-leg standing, only 8 participants from each Group adequately performed the squat task in our study, suggesting this task may be too challenging. Also, people with chronic hip pathologies may have developed pain avoidance strategies over time and could respond very differently to balance challenges in comparison to our participants. As such, these findings provide a foundation for more clinical research in this field.

CONCLUSION

Alterations in dynamic single-limb balance tasks involving lower limb reaching, forwards stepping and squatting, were observed irrespective of whether middle-aged adults were exposed to experimental pain or rest. The actual presence of hip muscle pain, in isolation from pathological changes, are unlikely to drive the balance impairments observed in middle-aged adults with musculoskeletal conditions. Short-term improvements in balance with task repetition were observed irrespective of condition. Further research is needed to explore how the presence of painful hip pathologies affect the neuromuscular control of balance in midlife.

Conflict of Interest: None to declare

REFERENCES

[1] Isles RC, Low Choy NL, Steer M, Nitz JC. Normal Values of Balance Tests in Women Aged 20–80. J Am Geriatr Soc 2004;52:1367-72.

[2] Low Choy N, Brauer S, Nitz J. Changes in postural stability in women aged 20 to 80 years. J Gerontol Med Sci 2003;58A:525-30.

[3] Nitz JC, Low Choy NL, Isles RC. Medial–lateral postural stability in community dwelling women over 40 years of age. Clin Rehabil 2003;17:765-7.

[4] Bouillon LE, Baker JL. Dynamic balance differences as measured by the Star Excursion Balance Test between adult-aged and middle-aged women. Sports Health 2011;3:466-9.

[5] Low Choy N, Brauer S, Nitz J. Linking stability to demographics, strength and sensory system function in women over 40 to support pre-emptive preventive intervention. Climacteric 2008;11:144-54.

[6] Nolan M, Nitz J, Low Choy NL, Illing S. Age-related changes in musculoskeletal function, balance and mobility measures in men aged 30–80 years. Aging Male 2010;13:

[7] Nitz JC, Low Choy N. The relationship between ankle dorsiflexion range, falls and activity level in women aged 40 to 80 years. NZ J Physiother 2004;32:121-5.

[8] Illing S, Low Choy NL, Nitz J, Nolan M. Sensory system function and postural stability in men aged 30–80 years. Aging Male 2010;13:202-10.

[9] Low Choy NL, Brauer SG, Nitz JC. Age-Related Changes in Strength and Somatosensation during Midlife: Rationale for Targeted Preventive Intervention Programs. Ann NY Acad Sci 2007;1114:180-93.

[10] Nitz JC, Low Choy NL. Changes in activity level in women aged 40-80 years. Climacteric 2007;10:408-15.

[11] Leveille SG, Bean J, Ngo L, McMullen W, Guralnik JM. The pathway from musculoskeletal pain to mobility difficulty in older disabled women. Pain 2007;128:69-77.

[12] Stubbs B, Binnekade T, Eggermont L, Sepehry AA, Patchay S, Schofield P. Pain and the risk for falls in community-dwelling older adults: systematic review and meta-analysis. Arch Phys Med Rehabil 2014;95:175-87.

[13] Hatton AL, Kemp JL, Brauer SG, Clark RA, Crossley KM. Impairment of dynamic single-leg balance performance in individuals with hip chondropathy. Arthritis Care Res 2014;66:709-16.

[14] Tateuchi H, Ichihashi N, Shinya M, Oda S. Anticipatory postural adjustments during lateral step motion in patients with hip osteoarthritis. J Appl Biomech 2011;27:32-9.

[15] Kiss RM. Effect of the degree of hip osteoarthritis on equilibrium ability after sudden changes in direction. J Electromyogr Kinesiol 2010;20:1052-7.

[16] Izumi M, Petersen KK, Arendt-Nielsen L, Graven-Nielsen T. Pain referral and regional deep tissue hyperalgesia in experimental human hip pain models. Pain 2014;155:792-800.

[17] Karni A, Meyer G, Rey-Hipolito C, Jezzard P, Adams M, Turner R, Ungerleider LG. The acquisition of skilled motor performance: Fast and slow experience-driven changes in primary motor cortex. Proc Natl Acad Sci U S A 1998;95:861-8.

[18] Kinzey S, Armstrong CW. The reliability of the Star-Excursion Test in assessing dynamic balance. J Orthop Sports Phys Ther 1998;27:356-60.

[19] Hill K, Bernhardt J, McGann AM, Maltese D, Berkovits D. A new test of dynamic standing balance for stroke patients: Reliability, validity and comparison with healthy elderly. Physiother Can 1996;48:257-62.

[20] Hatton AL, Crossley KM, Hug F, Bouma J, Ha B, Spaulding KL, Tucker K. Acute experimental hip muscle pain alters single-leg dynamic balance performance in healthy young adults. Gait Posture 2015;41:871-6.

[21] Melzack R. The short-form McGill questionnaire. Pain 1987;30:191-7.

[22] Australian Bureau of Statistics: National health survey: Summary of results, 2007-2008 (reissue). Canberra: Australian Bureau of Statistics; 2009.

[23] Stel VS, Smit JH, Pluijm SMF, Lips P. Balance and mobility performance as treatable risk factors for recurrent falling in older persons. J Clin Epidemiol 2003;56:659-68.

[24] Munro AG, Herrington LC. Between-session reliability of the star excursion balance test. Phys Ther Sport 2010;11:128-32.

[25] Hatta T, Ito Y, Matsuyama Y, Hasegawa Y. Lower-limb asymmetries in early and late middle age. Laterality 2005;10:267-77.

[26] Bennell K, Hinman RS. Effect of experimentally induced knee pain on standing balance in healthy older individuals. Rheumatology 2005;44:378-81.

[27] Bryant EC, Trew ME, Bruce AM, Kuisma RME, Smith AW. Gender differences in balance performance at the time of retirement. Clin Biomech 2005;20:330-5.

Figure 1: Reactive Sideways Stepping Task

Figure 2: Single-Leg Squat Task

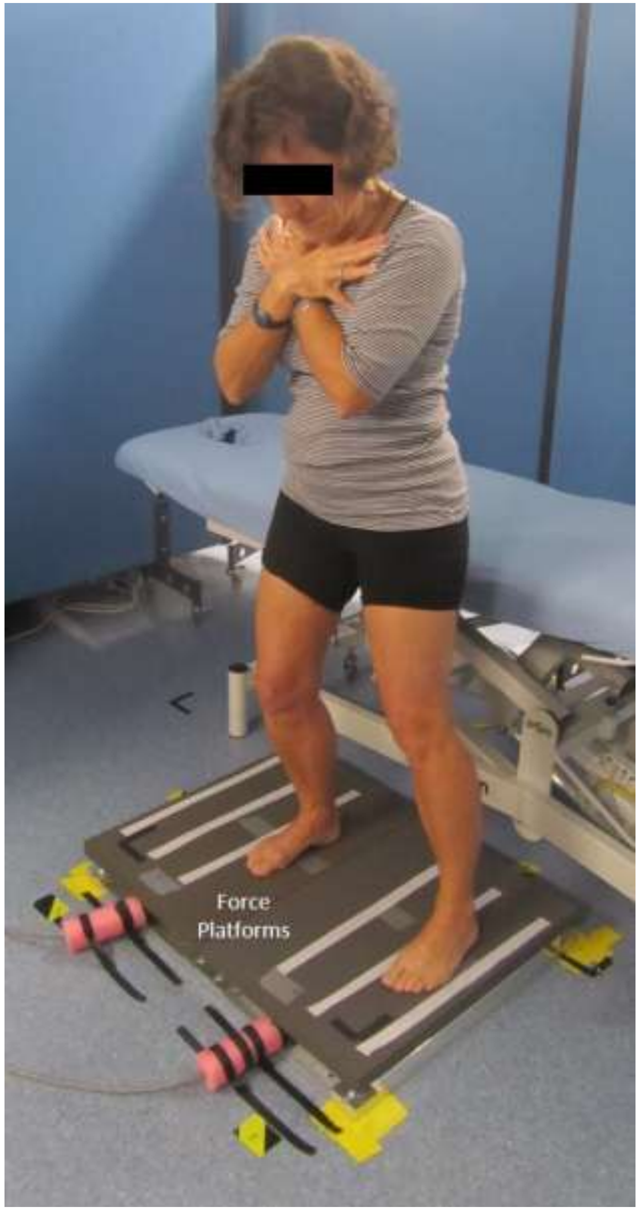
Figure 3: Significant main effects for Condition and Group across balance tasks

Table 1: Balance measures (Mean±SD) for each motor task. Centre of pressure movement during the Reactive Sideways Stepping task (Group-1, N=16 and Group-2, N=16[§]); Reach distance during the Star Excursion Balance Test (SEBT) (Group-1, N=16 and Group-2, N=17[§]); Number of steps taken during the Step Test (Group-1, N=16 and Group-2, N=18); and Centre of pressure movement during the Single-Limb Squat task (Group-1, N=8 and Group-2, N=8).

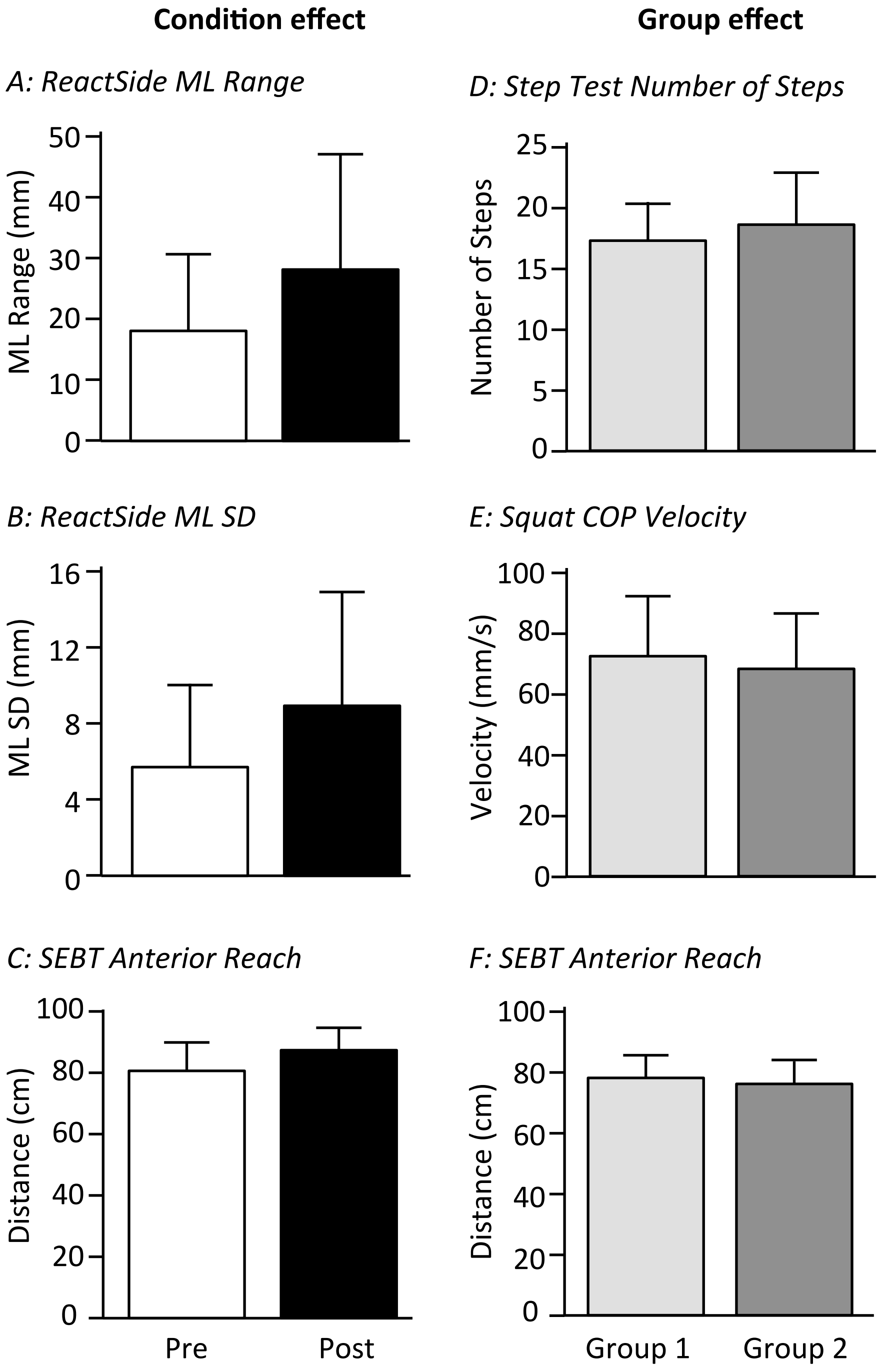
		Group-1				***Group-2***			
		No Pain		***Pain***		***Pre-Rest***		***Post-Rest***	
Task	**Balance measure**	*Left Leg*	*Right Leg*	*Left Leg*	*Right Leg*	*Left Leg*	*Right Leg*	*Left Leg*	*Right Leg*
Reactive Sideways Stepping	ML Range (mm)	16.0±8.4	16.9±11.5	17.1±9.0	21.7±19.7	26.3±20.1	28.3±21.1	29.3±17.3	28.8±20.0
	MLSD (mm)	5.5±2.9	5.5±3.6	5.1±3.0	7.2±6.6	8.5±6.1	9.0±6.5	9.3±5.2	9.3±6.4
	AP Range (mm)	26.6±11.8	33.1±12.4	26.0±15.6	34.2±16.1	32.5±11.7	29.5±10.6	28.5±11.9	25.1±8.9
	APSD (mm)	9.2±4.4	11.1±3.4	9.0±5.6	11.7±5.2	11.3±4.1	10.1±3.7	10.0±4.3	8.9±3.2
	Velocity (mm s^{-1})	134.0±43.3	158.2±68.5	140.1±68.3	166.2±76.6	177.1±79.0	176.1±63.2	183.0±90.8	170.6±66.5
SEBT	Anterior Reach (cm)	75.4±7.4	75.0±6.7	72.9±8.7	74.2±6.9	80.6±6.3	81.7±6.0	80.1±5.8	80.4±5.4
	Medial Reach (cm)	72.9±8.4	72.7±8.9	71.8±9.0	70.5±8.4	78.9±9.9	77.4±8.9	79.0±8.8	76.8±7.7
	Posteromedial Reach (cm)	70.7±10.0	70.9±9.8	69.9±10.5	69.7±8.6	75.1±11.1	74.2±9.0	74.7±10.3	73.4±6.7
Step Test	No. of Steps	16.5±3.9	16.9±4.0	18.3±5.0	18.6±5.2	18.1±2.5	18.2±2.3	19.3±2.6	19.4±3.4
Single-Limb Squat	ML Range (mm)	37.0±7.7	37.0±7.6	35.6±10.4	35.6±8.6	39.5±11.2	39.4±9.3	35.9±7.3	35.8±6.6
	MLSD (mm)	7.4±1.7	7.7±1.6	7.4±2.2	7.9±2.3	8.1±1.8	8.3±1.7	7.7±1.8	8.1±2.1
	AP Range (mm)	69.1±10.0	71.9±21.4	69.1±20.4	63.8±19.5	61.9±12.0	68.0±15.5	64.6±17.4	63.5±16.3
	APSD (mm)	14.7±2.7	14.6±3.5	14.4±1.6	14.0±4.3	12.3±2.3	13.3±1.4	13.2±2.4	12.5±2.4
	Velocity (mm s^{-1})	69.2±22.3	70.8±25.8	67.5±27.2	65.3±21.6	76.6±12.8	78.1±15.7	69.7±12.7	72.7±11.5

ML = mediolateral, AP = anterior-posterior, SD = standard deviation.

[§]Data is based on N=16 due to an error with the force platforms during the test procedures for two participants; and N=17, as measurements were not available post-rest for one participant


Force
Platforms


Electrogoniometer
Force
Platforms


Condition effect
Group effect
A: ReactSide ML Range
ML Range (mm)
50
40
30
20
10
0
D: Step Test Number of Steps
Number of Steps
25
20
15
10
5
0
B: ReactSide ML SD
ML SD (mm)
16
12
8
4
0
E: Squat COP Velocity
Velocity (mm/s)
100
80
60
40
20
0
C: SEBT Anterior Reach
Distance (cm)
100
80
60
40
20
0
Pre
Post
F: SEBT Anterior Reach
Distance (cm)
100
80
60
40
20
0
Group 1
Group 2