Individuals with Persistent Greater Trochanteric Pain Syndrome Exhibit Impaired Pain Modulation, as well as Poorer Physical and Psychological Health, Compared with Pain-Free Individuals: A Cross-Sectional Study

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Individuals with persistent greater trochanteric pain syndrome exhibit impaired pain modulation, as well as poorer physical and psychological health than pain free individuals: a cross sectional study

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Abstract

Objectives: To compare physical, sensory and psychosocial factors between individuals with greater trochanteric pain syndrome and controls, and to explore factors associated with pain and disability.

Design: Cross-sectional study.

Setting: General community.

Subjects: Patients with persistent, clinically diagnosed greater trochanteric pain syndrome and healthy controls.

Methods: Participants completed tests of thermal and pressure pain threshold; conditioned pain modulation; temporal summation; muscle strength, physical function, physical activity, psychological factors and health related quality of. Standardised mean differences between groups were calculated, and multiple linear regression identified factors associated with pain and disability.

Results: Forty patients (95% female, average (standard deviation) age 51 (9) years), and 58 controls (95% female, age 53 (11) years) were included. Heat pain threshold, temporal summation and pain catastrophizing were not different between groups. Compared to controls, patients displayed significantly poorer quality of life (standardized mean difference -2.66), lower pressure pain threshold locally (-1.47, remotely (-0.57)), poorer health status (-1.22), impaired physical function (range 0.64 to 1.20), less conditioned pain modulation (-1.01), weaker hip abductor/extensor strength (-1.01 and -0.59), higher depression (0.72) and anxiety (0.61) levels, lower cold pain threshold locally (-0.47, (remotely (-0.39)) and less time spent in (vigorous) physical activity (-0.43 to -0.39). 26% of pain and disability was explained by depression, hip abductor strength and time to complete stairs.

Conclusions: Patients with greater trochanteric pain syndrome exhibited poorer health related quality of life, physical impairments, widespread hyperalgesia, and greater psychological distress than healthy controls. Physical and psychological factors were associated with pain and disability.

Key words: Tendinopathy, musculoskeletal pain, chronic pain.

Introduction

Greater trochanteric pain syndrome (GTPS) presents as lateral hip pain on activities that load the structures at the greater trochanter. Most common in middle-aged females, it is the most prevalent lower limb tendinopathy to present to primary care (4.22 per 1000 per year) (1). GTPS often persists, and high levels of pain and disability and poor quality of life are reported (2). Pain self-efficacy, anxiety and depression are associated with other persistent musculoskeletal conditions (3, 4) and tendinopathies (5), however, the presence of psychological factors in persistent GTPS when compared to controls has not been studied.

There is evidence of local and widespread mechanical and thermal hyperalgesia in upper limb tendon studies, with discrepancies seen in lower limb studies (6-9). These lower limb studies are limited by low sample size and high methodological heterogeneity including testing methods, sites of assessment and equipment (7). Currently, there is one cross-sectional study available in GTPS that reports local and widespread mechanical hyperalgesia in GTPS (n = 18) compared to controls (n = 18) (8). Altered endogenous pain inhibitory mechanisms have been reported in several chronic musculoskeletal conditions like osteoarthritis (10), low back pain (11, 12), Achilles tendinopathy (9), and recently in GTPS (13). The latter study reported a negative condition pain modulation in 34.7% of GTPS participants, although there was no comparator group included. Investigation of a more comprehensive battery of sensory tests in people with persistent greater trochanteric pain is warranted.

The gluteal muscles are crucial for functions like walking and stair climbing (14). Hip abductor weakness is observed unilaterally (15-17) and bilaterally (15, 16) in GTPS, but hip extensor muscle strength has received limited attention.

Our primary aim was to quantify differences in physical, sensory, and psychosocial outcome measures in participants with GTPS compared to pain-free controls. Based on the current literature, we hypothesized that impaired physical strength and function, mechanical hyperalgesia and psychological distress would be found in persistent GTPS compared to pain-free controls. Our secondary aim was to identify factors associated with pain and disability in participants with GTPS. We hypothesized that pain and disability would be explained by multidimensional patient factors.

Methods

Study design

This cross-sectional study compared individuals with GTPS and age and sex matched controls. Reporting follows the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines for cross-sectional studies (18). Ethical approval was granted by The University of Queensland Human Research Ethics Committee (approval #2015000219). All participants provided verbal and written consent.

Setting

Between 16 May 2017 and 11 September 2018, participants were recruited from the Brisbane metropolitan area via newsletters and social media. A three-stage eligibility screening process was adopted: online screening, telephone interview and physical screening. Physical screening was performed by a registered post-graduate qualified musculoskeletal physiotherapist with >20 years clinical experience and baseline measures were conducted

during one session of approximately 2.5 hours in a sound and temperature controlled room at The University of Queensland.

Participants

Volunteers were aged 18-70 years. Individuals with GTPS were eligible if they experienced lateral hip pain rated ≥2/10 on an 11-point Numeric Rating Scale (NRS) (0 = no pain; 10 = worst pain imaginable) at its worst in the past week; pain duration ≥3 months; pain on palpation of the tendon insertion on the greater trochanter (19), plus reproduction of trochanteric pain on at least one of the following clinical tests: (1) 30s single leg stance, (2) the Hip FADER test, (3) static muscle test in the FADER position, (4) the FABER test, (5) Ober's test, (6) a static muscle contraction in the Ober's test position (19). GTPS participants were excluded if they experienced groin pain on quadrant testing >3/10 PNRS, received a corticosteroid injection in the previous six months, experienced major trauma in the past 12 months, or had lower limb or back pain that was worse than their hip pain, required treatment or prevented usual work or leisure activities in the previous six months. Controls were excluded if they had lateral hip pain or other areas of pain requiring treatment or preventing work or leisure activities in the preceding six months. Pregnancy, systemic inflammatory or neurological disorders, uncontrolled diabetes, and fibromyalgia were general exclusion criteria.

Outcome measures

Data collection was performed by one researcher (MP) not blinded to the condition of the participants.

Pain and disability

Average pain, worst pain and pain during activity in the past week were rated using a PNRS. Pain and disability was measured using the Victorian Institute of Sports Assessment – GTPS (VISA-G) questionnaire (20), consisting of eight items. Scores range from 0 to 100, with higher scores indicating less pain and better function. The VISA-G demonstrates good test-retest reliability (ICC 0.827; 95% CI 0.638-0.923), internal consistency (Cronbach's alpha 0.809; 95% CI 0.709-0.934) and construct validity, compared to the Harris Hip Score and the Oswestry Disability Index (20).

Quantitative sensory testing

Somatosensory profiles were assessed unilaterally at a local hip site (the most painful spot in GTPS; 1-2cm posterior to the greater trochanter in controls) and a remote site (the lateral elbow, side randomly allocated by a coin toss). In participants with bilateral symptoms, the most affected side was measured. The order of quantitative sensory tests (QSTs) was standardized as follows.

Pain thresholds were determined by asking participants to 'press a button at the first onset of pain'. Cold pain threshold (CPT) and heat pain threshold (HPT) were assessed using a Thermotest Analyser (Somedic AB, Farsta, Sweden). From a baseline temperature of 32°C, incremental increases/decreases in temperature (1°C /s) were applied and tests were

terminated when the participant pressed the button or if upper (50°C) or lower (5°C) cut-off temperatures were reached. Pressure pain threshold (PPT) was assessed by placing a 1cm^2 probe of a handheld pressure algometer (Somedic, Sweden) on the skin and gradually increasing the pressure at a rate of 30kPa/s, until the participant pressed the button. A maximum pressure of 900 kPa could be applied. Average pain thresholds were calculated from three consecutive measurements with 30-second rest intervals.

Temporal summation was measured as the difference in perceived intensity (PNRS) between a single pinprick stimuli (256 mN pinprick) and the average of 10 repetitive pinprick stimuli applied within an area of 1cm^2 at 1/s. Five series were applied with 30-second rest intervals.

Conditioned pain modulation (CPM) was assessed by immersing the contralateral hand in a cold-water bucket (conditioning stimulus) and measurement of PPT over the lateral hip (test stimulus) before, during and immediately after immersion of the hand (21). The starting water temperature was 10°C (range 9.5°C – 10.5°C). Water temperature was adjusted by adding warm or cold water until a pain intensity of 4-6/10 on PNRS was reported. The highest PPT score recorded during or immediately post immersion of the hand was subtracted from the PPT score pre-immersion to calculate the CPM response. A positive CPM response (increase) reflects a hypo-algesic response, whereas a negative response (decrease) reflects a hyper-algesic response.

Strength and Physical measures

Hip abductor and extensor muscle strength were measured using a handheld dynamometer (Nicholas, Lafayett, IN47903 USA) (Figure 1). The center of the dynamometer was placed 5 cm proximal to the lateral malleolus for testing hip abductor strength, and in line with the posterior aspect of the thigh, 5 cm proximal from the kneecap for testing hip extensor strength (22). One practice and three experimental trials of maximal voluntary effort were conducted with 30-second rest intervals. Strength was reported as torque standardized to body weight (Nm/kg).

>>Insert Figure 1<<

Physical function was measured through balance (Star Excursion Balance Test (SEBT)) (23) and time to complete a 20-meter walk test (20MWT), five times sit to stand test (STS), and a flight of stairs. For the SEBT, participants were asked to maintain single leg stance while maximally reaching with the contralateral leg in anterior, posterolateral, and posteromedial directions (24). The 20MWT and flight of stairs were performed on a 10-meter course and a set of 11stairs that participants were asked to respectively complete/ ascend and descend as fast as they were able to, without running (25). STS was performed from a seated position, with arms across the chest, and participants stood up and down five times as quickly as possible (26). One practice trial and two testing trials with 3-minute rests were performed, and the fastest trial was used for analysis.

Physical activity time was determined with the Active Australia Survey (27). Participants reported minutes spent in walking, and performing moderate, and vigorous activity during the

previous week. Total physical activity was calculated as the sum of minutes spent in these activities.

Self-reported psychosocial outcomes and health related quality of life

Quality of life was measured with the EuroQoL questionnaire (28). Participants rated their current level of disability (severe, moderate or none) in five dimensions (mobility, self-care, usual activities, pain/discomfort, anxiety/depression). Responses were transformed into a single index score ranging from 0 to 1, with higher scores reflecting greater quality of life (28). Health status was measured on a visual analogue scale of the EuroQol, ranging from 0 (worst health you can imagine), to 100 (best health you can imagine). The EuroQol has demonstrated moderate validity and reliability (29, 30).

Pain catastrophizing was quantified with the self-reported Pain Catastrophizing Scale (PCS), that has high reliability (Cronbach's alpha = 0.91) and moderate construct validity compared to the Inventory of Negative Thoughts in Response to Pain (31). Participants indicated the degree to which they experience each of 13 thoughts or feelings when in pain on a 5-point scale, ranging from 0 (not at all), to 4 (all the time) (32). Total scores range from 0-52, higher scores indicating higher levels of pain catastrophizing (32). A total score ≥30 was defined as clinically relevant (32).

Anxiety and depression were measured with the Hospital Anxiety and Depression Scale (HADS) (33). Total anxiety and depression scores ranged from 0-21, higher scores indicating higher levels of anxiety and depression. Cases of anxiety and depression were defined by a

total score ≥8(33). The HADS has good reliability (Cronbach's alpha 0.82 and 0.83) and validity (33).

Fear of movement (kinesiophobia) was measured with the Tampa Scale of Kinesiophobia (TSK) (34), asking participants to rate their agreement on a 4-point Likert scale, ranging from 1 (strongly disagree), to 4 (strongly agree). Total scores range from 17 to 68, with higher scores indicating greater kinesiophobia. High fear was defined as a total score >37, low fear as a total score ≤37 (34). The TSK has reported good reliability (Cronbach's alpha 0.74 - 0.87) and validity (35).

Pain self-efficacy was measured with the Pain Self-Efficacy Questionnaire (PSEQ), a questionnaire used to assess confidence in performing activities while in pain (36). Participants rate how confidently they can perform activities described on a 7-point Likert scale, ranging from 0 (not at all confident), to 6 (completely confident). Total scores range from 0 to 60, where higher scores reflect stronger self-efficacy beliefs (36). Scores <40/60 were identified as participants having "less sustainable gains," as opposed to scores ≥40 identifying participants that "could maintain functional gains" (36). The PSEQ is shown to be a valid and reliable measure (37).

Study Size

Sample size calculations were done a-priori with G*Power (Universitat Dusseldorf) v3.1(38), based on values of the remote PPT measure in lateral elbow tendinopathy (39). Based on a

moderate effect size of 0.67 (39), power of 0.8, alpha of 0.05, and a 2:1 allocation ratio, we estimated a total sample size of 36 GTPS and 72 control participants.

Statistical Method

Statistical analyses were performed in SPSS version 25.0 (IBM, New York, NY, USA). Normality was assessed visually (histograms, quantile-quantile plots).

Differences between GTPS and controls were assessed using parametric tests for continuous outcome measures (independent t-tests) and non-parametric tests for ordinal and nominal data (Mann-Whitney U test, Chi-square test). CPM efficacy was analysed using ANCOVA, including baseline hip PPT, water temperature and pain ratings of the conditioning stimulus prior to PPT testing as covariates. Significance was determined with the Benjamini-Hochberg procedure to control for possible false positives caused by multiple comparisons (40). The false discovery rate was set at 0.10 (10%).

Standardized mean differences (SMDs) and 95% confidence intervals (CI) were calculated to facilitate comparison for outcomes with different measurement units (RevMan V5.0; random effect model). Effect sizes were considered as: 0.2 small, 0.6 moderate, 1.2 large and ≥2.0 very large (41).

Correlations between pain intensity, number of pain regions and all outcome measures were calculated to evaluate the degree of association of these commonly regarded co-factors in presentation of musculoskeletal pain. Pearson correlation coefficients of (negative) 0.0 to 0.3 were regarded as negligible, 0.30 to 0.50 low, 0.5 to 0.7 moderate, 0.7 – 0.9 high, and 0.9 to 1.0 very high.

Multiple linear regression analysis ('*Enter'* method) was performed with variables that were (a) continuous, (b) significantly impaired compared to controls (variables with highest effect sizes were chosen if they measured similar constructs), (c) significantly correlated with VISA-G. Symptom duration and pain intensity during activity were considered possible confounders. Independent variables were sequentially excluded from the model based on magnitude of significance. Multicollinearity reflected by a VIF of <2 was considered respectable.

Results

Forty participants with GTPS and 58 controls were recruited (Figure 2). GTPS and controls were comparable in age and sex, the majority being female (Table 1). GTPS participants had a significantly greater BMI, waist girth and hip circumference compared to controls (Table 1). Within the GTPS group, 35% had a normal BMI, 32.5% were classified overweight, 17.5% class I obesity, 7.5% class II obesity, and 7.5% class III obesity compared to 3.4% underweight, 63.8% normal, 22.4% overweight and 10.3% class I obesity in controls ($p<0.01$, Table 1)(42).

>>Insert Figure 2<<

>>Insert Table 1<<

Outcome measures

Sensory, physical and psychological outcomes, and mean differences (95% CI) are presented in Table 2 and Supplementary Material 1 outlines significant p-values.

>>Insert Table 2<<

Quantitative Sensory Testing

Compared to controls, GTPS displayed large differences in local PPT and small differences in remote PPT. Small differences in local and remote CPT (GTPS displaying cold hyperalgesia) were noted. HPT and temporal summation did not differ between groups.

CPM was measured for 39 GTPS and 41 controls (Figure 3). One GTPS and three control participants did not consent to CPM testing, three controls could not be measured due to time constraints or skin condition, and nine controls reached >900kPa during PPT or CPM testing. Moderate differences were found between groups, with GTPS displaying smaller changes in PPT (Table 2, Figure 4).

Low associations were found for worst pain and local HPT ($r = -0.37$, $p = 0.02$; as was average pain), local temporal summation ($r = 0.48$, $p < 0.01$) and local PPT ($r = -0.37$, $p = 0.02$). No significant associations were found between the number of pain regions and any of the QST measures including temporal summation and CPM.

Multimodal nature of GTPS

>>Insert Figure 3 and Figure 4<<

Strength and Physical measures

GTPS showed large differences in STS performance and moderate differences for unilateral hip abductor strength, 20MWT, flight of stairs, and SEBT performance (all directions) compared to controls. A small reduction in hip extensor strength was observed (Table 2, Figure 4).

Significant but small group differences were found for total physical activity time and vigorous physical activity in the previous week (Table 2, Figure 4).

Low associations were found for worst pain and SEBT posteromedial ($r = -0.35$, $p = 0.04$; as was average pain), flight of stairs ($r = 0.47$, $p<0.01$; as was average pain $r = 0.41$, $p = 0.01$), STS ($r = 0.41$, $p = <0.01$), and extensor strength ($r = -0.36$, $p = 0.03$). No significant associations were found between the number of pain regions and any strength or physical measures.

Self-reported psychological distress and quality of life

Compared to controls, GTPS displayed large differences in quality of life, health status and moderate differences in anxiety and depression scores. No significant group differences were found for pain catastrophisation (Table 2, Figure 4). Within the GTPS group, 25% were classified with anxiety, 5% with depression, compared to 5.2% and 3.4% of controls respectively. (Table 2). Within the GTPS group, 87.5% were able to 'maintain functional gains' (PSEQ scores), whereas 57.5% had a high degree of kinesiophobia (Table 2). These measures were not collected in the control group.

Low associations were found for worst pain and anxiety (r = -0.33, p = 0.04), health status (r = -0.48, p<0.001; as was average pain r = -0.49, p<0.001), and for the number of pain sites and pain catastrophising (r = 0.43, p<0.01). High associations were found for worst pain and quality of life (r = -0.75, p<0.001; as was average pain r = -0.73, p<0.001).

Factors associated with pain and disability (VISA-G)

The final multivariate regression model explained 26% of the variance of VISA-G. Cases with evidence of marginal significance were retained in the final model. Based on the non-standardised coefficients, one unit increase in depression on the HADS is likely to decrease VISA-G by 1.67 units, one $N.m.kg^{-1}$ increase in abductor strength is likely to increase VISA-G by 12.64 units, and one second increase in time to complete stairs is likely to decrease VISA-G by 0.53 units (Supplementary Material 2).

Discussion

This study aimed to quantify differences in physical, sensory, and psychosocial outcome measures in participants with GTPS compared to pain-free controls, and to explore the factors associated with pain and disability. Large effects were found for health-related quality of life, hip PPT, and STS; moderate effects for CPM, hip abductor strength, all other functional measures, anxiety and depression; small effects for elbow PPT, hip and elbow CPT, hip extensor strength and physical activity time. Notably we did not find any differences in temporal summation of pain between groups. VISA-G scores were explained by a combination of depression, hip abductor strength and time to complete stairs.

Multimodal nature of GTPS

This study found evidence of widespread mechanical and cold hyperalgesia. The degree of impairment in PPT was greater at the local tendon (SMD -1.49) than the elbow (SMD -0.58), and small for local and remote CPT (SMD -0.47 and -0.39). Previous literature reported evidence of *local* mechanical and thermal hyperalgesia in some, but not all lower tendinopathy studies (7-9, 43). *Widespread* mechanical and cold hyperalgesia have been reported in Achilles and lateral elbow tendinopathy (9, 39), but not in other studies (43). A recent cross-sectional study in persistent GTPS reported significant group differences in PPT locally, bilaterally and remotely, inferring primary and secondary mechanical hyperalgesia in GTPS (8). Comparison of our study results with previous literature shows inconsistencies in findings. High quality methodological studies with a larger sample size that explore the involvement of pain sensitivity in persistent tendinopathies like GTPS are warranted.

CPM is an established paradigm used to study endogenous pain inhibitory mechanisms. It is thought to reflect the efficacy of the diffuse noxious inhibitory control system (DNIC) (44), a spinal-medullary-spinal pathway that triggers pain inhibition when two painful stimuli are applied simultaneously (45). In humans, CPM may reflect peripheral neural mechanisms, such as chronic inflammation and hyper-excitability (46) as well as higher cortical centres, which are also affected by age, sex, menstruation cycle, and psychological features (45). We found moderate differences in CPM efficacy, possibly reflecting alterations in DNIC, however we did not find evidence of altered facilitatory ascending mechanisms in GTPS (i.e., temporal summation was not different between groups). We could speculate that persistent pain causes ongoing activation of pain inhibitory mechanisms, leaving patients unable to further activate these systems, resulting in a ceiling effect. This has been previously proposed in other persistent pain conditions (47).

Multimodal nature of GTPS

The presence of widespread pain sites is often considered linked with central nervous system sensitization. We did not find this in our cohort, which is consistent with a study of knee osteoarthritis (48), but not others. A recent cross-sectional study including 49 participants with GTPS reported significant associations of widespread pain distribution with less CPM and increased temporal summation (13). The association between widespread pain and less CPM has also been reported in low back pain (11, 49). It might be that a subgroup of individuals who have GTPS and widespread pain may be more likely to experience central nervous system sensitization. Future research should further assess if subgroups of individuals with different severity of GTPS vary according to their pain distribution. This may lead to improved patient specific pain management.

The VISA-G is a self-reported questionnaire concerning pain and functional disability specifically designed for GTPS (20). Linear regression revealed a strong association between VISA-G and depression, implying depression levels to be an indicator of severity of self-reported pain and disability. High quality evidence shows depression levels to be associated with many other chronic musculoskeletal pain conditions (50, 51), and reported depression to be a possible moderator in the relationship with chronic pain (52). Further, positive behaviours like resilience, optimism and pain acceptance are thought to positively affect chronic pain (53, 54). Thus, the interpretation of self-reported pain and disability questionnaires, such as VISA-G, should take this association with levels of depression into account.

The limitations of this study include the unblinded assessor, although a standardized protocol was rigorously followed. Only 80% of the calculated sample size for controls was recruited due to time constraints. Further, our population was highly educated (>65% of both groups had at least graduated from University or polytechnic) and predominantly female, which should be taken into account when generalizing findings. QST requires operator skill, however, members of this research lab have considerable experience in QST studies. Future research should aim to identify the prognostic significance of physical, sensory and psychological characteristics on pain and disability in persistent GTPS before targeted treatments can be developed. In addition, the impact of social factors and environment should be further investigated to understand the patient characteristics and prognosis of individuals with GTPS.

Conclusions

This study shows that compared to controls, people with persistent GTPS exhibit impaired health related quality of life, physical strength and functioning, widespread hyperalgesia, and altered psychological factors. No differences were seen in heat hyperalgesia, temporal summation or pain catastrophizing. Self-reported pain and disability was associated with depression, hip abductor strength and time to complete stairs. The connections between biopsychological features and persistent pain in GTPS should be considered in order to and inform management approaches.

Acknowledgments and Conflict of Interest

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Tables

Table 1. Participant characteristics of the GTPS and the control group. Data represent mean (SD) for each group unless otherwise indicated, with group mean differences (95% CI; p-value). Significant group differences are indicated by *.

	GTPS group n = 40	Control group n = 58	Group difference
Age years	51 (9)	53 (11)	-1.2 (-5.5, 3.1; p=0.59)
Sex female n, (%)*	38 (95%)	55 (95%)	p = 0.97
Height cm	165.7 (6.8)	165.7 (5.7)	0 (-0.0, 0.0; 1.0)
Body mass kg	78.3 (18.5)	66.2 (12.8)	12 (5.7, 18.3; p<0.001*)
Body Mass Index kg/m^2	28.5 (6.2)	24.0 (4.1)	4.4 (2.3, 6.5; p<0.001*)
Underweight (BMI <18.5)	0%	3.4%	p <0.01*†
Normal (18.5–24.9)	35%	63.8%	
Overweight (25.0–29.9)	32.5%	22.4%	
Obese class I (30.0–34.9)	17.5%	10.3%	
Obese class II (35.0–39.9)	7.5%	-	
Obese class III (≥40)	7.5%	-	
Waist girth cm	94.7 (14.0)	84.12 (13.3)	10.6 (5.1, 16.2; p<0.001*)
Hip circumference cm	110.5 (13.9)	101.4 (10.2)	9.1 (4.3, 14.0; p<0.001*)
Highest education†			p = 0.28
Less than 3y high school n, (%)	1 (2.5)	1 (1.7%)	
3y or more high school n, (%)	5 (12.5%)	2 (8.6%)	
Some tertiary training n, (%)	8 (20%)	9 (15.5%)	
Graduated from University or polytechnic n, (%)	11 (27.5%)	19 (32.8%)	
Any post-graduate study n, (%)	15 (37.5%)	24 (41.4%)	
Work status†			p = 0.91
Employed for wages n, (%)	26 (65%)	35 (60.3%)	
Self-employed n, (%)	4 (10%)	3 (5.2%)	
Out of work n, (%)	1 (2.5%)	2 (3.4%)	
A homemaker n, (%)	3 (7.5%)	1 (1.7%)	
Student n, (%)	6 (15%)	4 (6.9%)	

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Retired n, (%)	0	13 (22.4%)	
Hip pain interference with sleep quality			-
Not at all n, (%)	4 (10%)	-	
Occasionally n, (%)	9 (22.5%)	-	
Some of the time n, (%)	16 (40%)	-	
Most of the time n, (%)	7 (17.5%)	-	
All of the time n, (%)	4 (10%)	-	
Duration of symptoms months, median (IQR)	18 (15)	-	-
Unilateral n, (%)	28 (70%)	-	-
VISA-G (0-100)	63 (11)	-	-
Pain severity in past week (PNRS 0-10)			
Average, median (IQR)	4 (3)	-	-
Worst, median (IQR)	7 (3)	-	-
During activity, median (IQR)	5 (4)	-	-
Number of pain regions, median (IQR)‡	3 (2)		

Abbreviations: BMI, body mass index; GT, gluteal tendinopathy; IQR, interquartile range; PNRS, pain numeric rating scale; SD, standard deviation; VISA-G, Victorian Institute of Sports Assessment – Gluteal tendinopathy; 3y, 3 years.

*significant p level set on p = 0.05

†Group differences calculated with the $\chi 2$ test.

‡Number of pain regions recorded with The Nordic Musculoskeletal Questionnaire (55).

Table 2. Mean (SD) for quantitative sensory testing, strength and physical tests, psychological self-reported outcome measures, and quality of life in the GTPS and control groups, with group mean differences (95% CI; p-value).

	GTPS group n = 40	Control group n = 58	Group differences
QST measures			
Cold pain threshold hip °C	10 (7.52)	7.02 (5.24)	2.97 (0.41, 5.53; 0.03*)
Cold pain threshold elbow °C	10.40 (7.77)	7.79 (5.85)	2.60 (0.13, 5.53; 0.08*)
Heat pain threshold hip °C	45.09 (2.84)	46.09 (2.76)	-1.00 (-2.14, 0.14; 0.09)
Heat pain threshold elbow °C	46.05 (3.59)	46.82 (2.80)	-0.78 (-2.06, 0.50; 0.23)
Pressure pain threshold hip kPa	203.25 (71.99)	395.88 (155.59)	-192.63 (-245, -140.26; <0.001*)
Pressure pain threshold elbow kPa	317.83 (133.81)	396.48 (134.96)	-78.66 (-133.53, -23.79; <0.01*)
Temporal summation hip /10 PNRS	1.33 (1.01)	1.16 (1.33)	-0.17 (-0.67 to 0.34; 0.51)
Temporal summation elbow /10 PNRS	0.58 (0.69)	0.73 (1.08)	0.15 (-0.21 to 0.50; 0.42)
Conditioned pain modulation hip kPa†	48.96 (51.48)	117.98 (79.31)	-59.79 (-98.22, -21.36; <0.01*)
Strength and physical measures			
Hip abductor strength $N.m.kg^{-1}$	0.70 (0.25)	1.00 (0.31)	-0.30 (-0.42, -0.18; <0.001*)
Hip extensor strength $N.m.kg^{-1}$	0.42 (0.20)	0.58 (0.30)	-0.16 (-0.27, -0.05; <0.01*)
Star Excursion Balance Test			
Anterior	0.52 (0.07)	0.58 (0.07)	-0.05 (-0.08, -0.03; <0.001*)
Posterolateral	0.78 (0.12)	0.86 (0.13)	-0.08 (-0.13, -0.03; <0.01*)
Posteromedial	0.66 (0.13)	0.77 (0.14)	-0.11 (-0.16, -0.05; <0.001*)
Sit to stand test s	11.98 (3.15)	8.76 (2.23)	3.22 (2.15, 4.30; <0.001*)
20 meter walk test s	9.84 (2.87)	7.42 (1.26)	2.42 (1.58, 3.27; <0.001*)
Flight of stairs test s	20.94 (5.47)	16.93 (3.64)	4.01 (2.18, 5.84; <0.001*)
Total physical activity min/week	465.38 (472.25)	677.16 (502.27)	211.78 (11.76, 411.80; 0.04*)
Vigorous physical activity min/week	98.25 (163.13)	166.98 (182.09)	68.73 (-2.54, 140.01; 0.06*)
Psychosocial self-reported outcome measures			
Pain catastrophizing scale			

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Total score /52	7.23 (6.56)	5.55 (7.0)	1.67 (-1.10, 4.45; 0.23)
Clinical level n, (%)‡	1 (2.5%)	1 (1.7%)	p = 0.79
Non clinical level n, (%)‡	39 (97.5%)	57 (98.3%)	
Hospital Anxiety and Depression			
Scale: Anxiety	5.38 (3.43)	3.43 (2.96)	1.94 (0.66, 3.23; <0.01*)
Total score /21	10 (25%)	3 (5.2%)	p<0.01
Cases n, (%)‡	30 (75%)	55 (94.8%)	
Non-cases n, (%)‡			
Hospital Anxiety and Depression			
Scale: Depression	3.15 (2.476)	1.52 (2.096)	1.63 (0.71, 2.55; 0.001*)
Total score /21	2 (5%)	2 (3.4%)	p = 0.70
Cases n, (%)‡	38 (95%)	56 (96.6%)	
Non-cases n (%)‡			
Pain self-efficacy			
Total score /60	49.58 (8.258)	-	-
Less sustainable gains n, (%)	5 (12.5%)	-	-
Maintenance of function n, (%)	35 (87.5%)	-	-
Tampa Scale of Kinesiophobia			
Total score /68	35.93 (4.599)	-	-
High degree of kinesiophobia n, (%)	23 (57.5%)	-	-
Low degree of kinesiophobia n, (%)	17 (42.5%)		
EQ-5D-3L			
Index score /1	0.72 (0.14)	0.98 (0.06)	-0.26 (-0.30, -0.22; <0.001*)
Self-reported health /100 VAS	68.68 (15.50)	84.21 (10.16)	-15.53 (-20.67, -10.39; <0.001*)

Abbreviations: GT, gluteal tendinopathy; PNRS, pain numeric rating scale SD, standard deviation; VAS, visual analogue scale.

*Significance calculated with the Benjamini-Hochberg procedure (Supplementary Material 1).

†Group differences calculated with an ANCOVA with GT n = 39 and HC n = 41.

‡Group differences calculated with the $\chi 2$ test.

Figure legends

Figure 1. Positioning of the participant during measurements of hip abductor muscle strength (upper image) and hip extensor muscle strength (lower image). Hip abductor muscle strength was measured with the test knee extended and the hip at 10° abduction and 0° flexion, and the opposite leg flexed at the hip (45°) and knee (90°). Hip extensor strength was measured with both hips in 30° flexion and both knees in 45° flexion. In both tests, the pelvis was stabilized with a seatbelt and towel, strapped to the plinth, and the participant held the side(s) of the plinth with both hands.

Figure 2. Flowchart of recruitment.

Figure 3. Individual data points of the greater trochanteric pain syndrome (GTPS) group (blue colour scheme; n =39) and control group (grey colour scheme; n = 41) and the group average (black line) for the pressure pain threshold (PPT) measure pre conditioning stimulus and the PPT max (maximum of PPT during/after).

Figure 4. Forest plot including standardized mean differences (SMD) and 95% confidence intervals (CI) for all outcome measures. Quantitative sensory testing on the hip and elbow (cold pain threshold (CPT), heat pain threshold (HPT), pressure pain threshold (PPT) and conditioned pain modulation (CPM)); strength (abductor and extensor), physical function (star excursion balance test (SEBT), time to complete 20 meter walk test, sit to stand, flight of stairs) and physical activity (Active Australia Survey (AAS); psychological outcome measures (the Hospital Anxiety and Depression Scale (HADS)), and the Pain Catastrophizing Scale (PCS)); health related quality of life.

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Figures

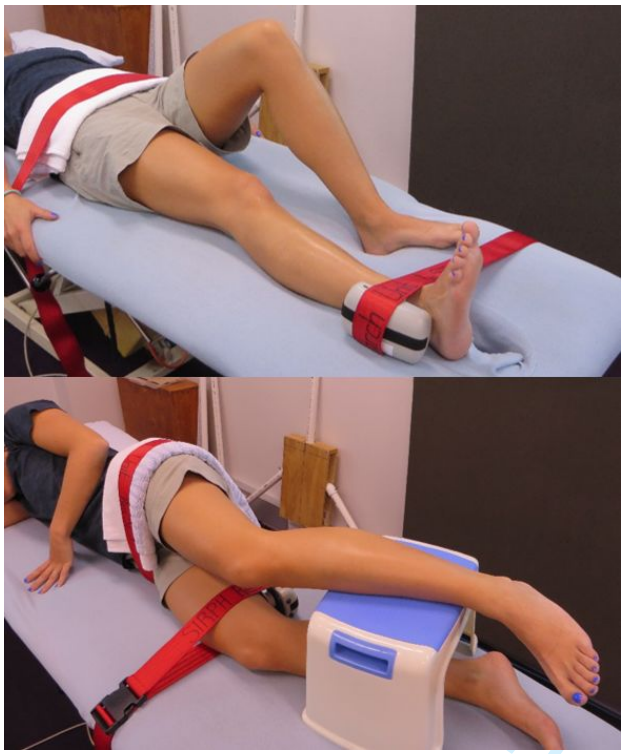

Figure 1.

Multimodal nature of GTPS

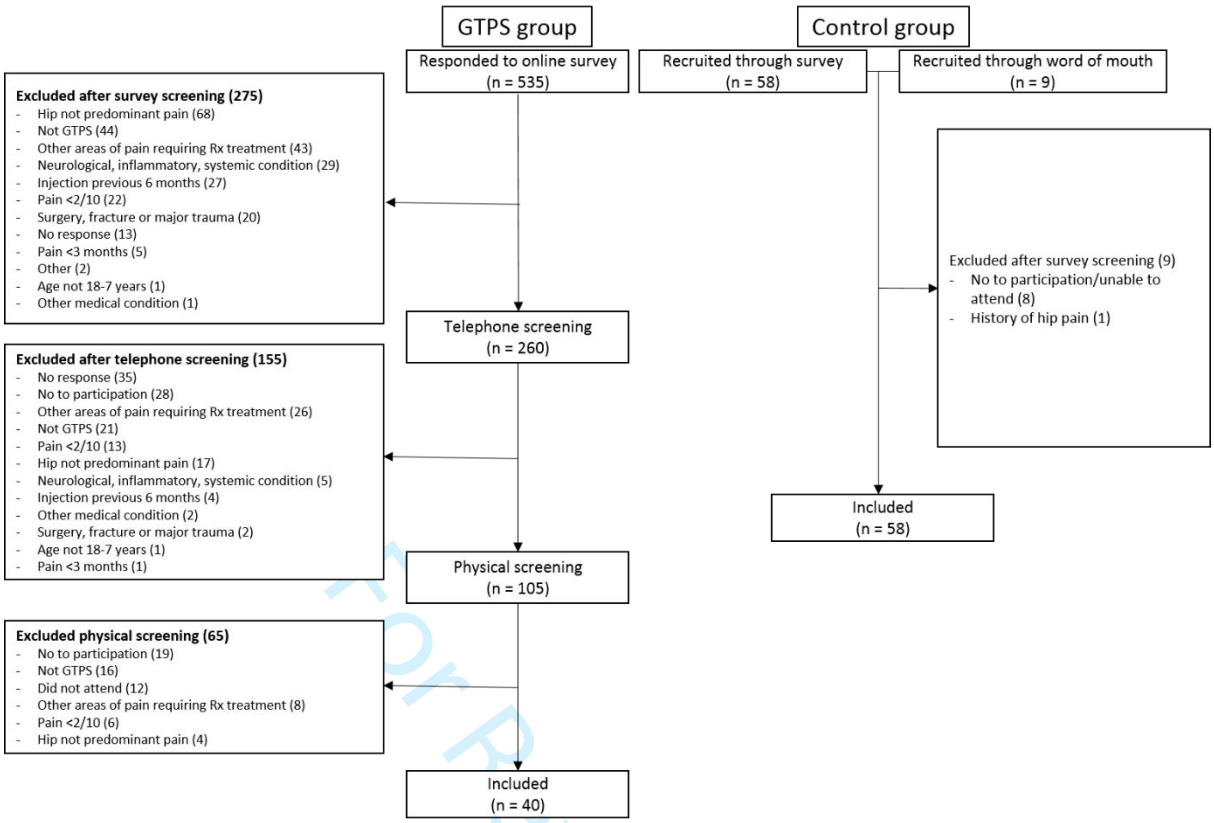

Figure 2.

Multimodal nature of GTPS

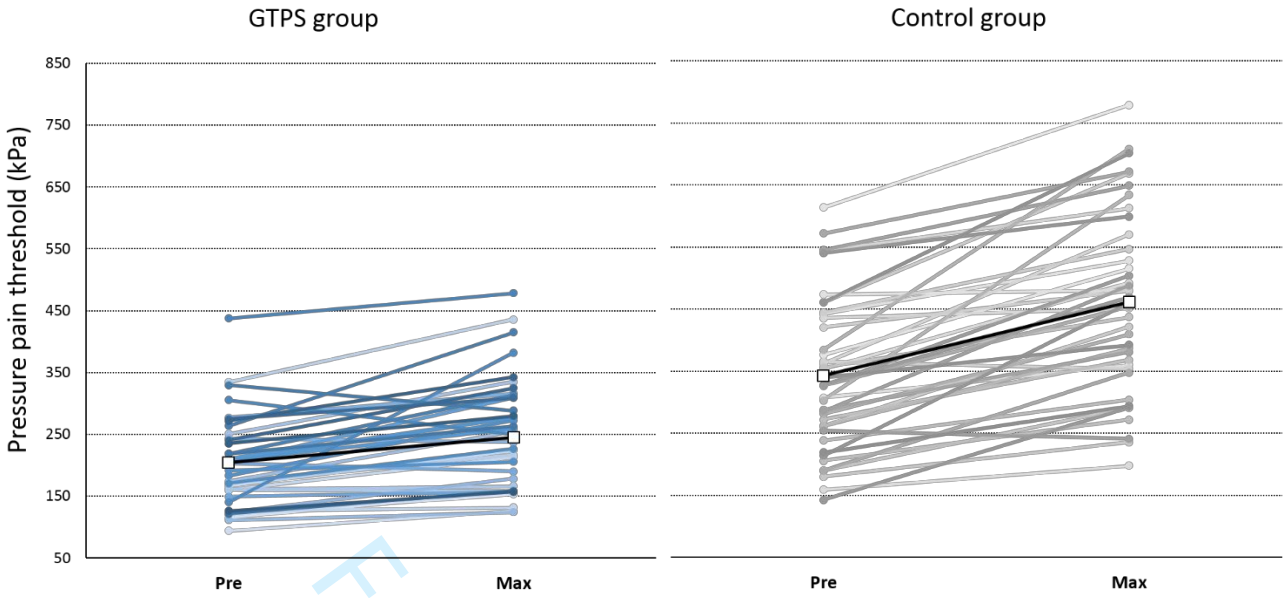

Figure 3.

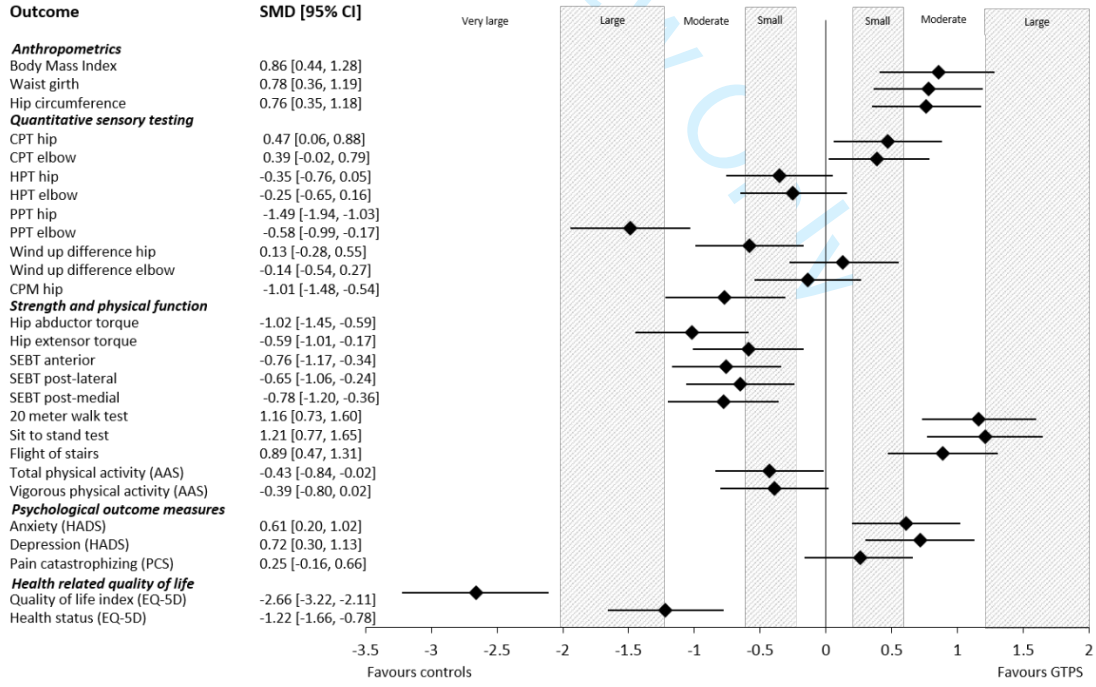

Figure 4.