Standing and Walking Balance in Patients with Chronic Shoulder Pain: A Case–control Study

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Abstract

Background: Patients with shoulder pain may have proprioceptive and balance deficits. However, studies on balance in patients with shoulder pain are scarce.

Objective: This study aims to investigate if patients with chronic shoulder pain demonstrate deficits in standing and walking balance and to study the relationship between outcome measures of balance and age and body mass index (BMI).

Materials and Methods: This case–control study was conducted at Dammam Medical Complex, Dammam, Saudi Arabia, between March and November 2018. The study recruited patients (n = 15) with chronic shoulder pain (>4 months) and healthy controls (n = 15) matched for age, gender and BMI. Standing balance was tested using a Challenge Disc test, the Romberg test and timed unipedal stance test (UPST). Walking balance was assessed using the timed up and go (TUG) test, stance phase duration and center of pressure (COP) deviation. Independent t-tests were used to investigate the differences between the two groups in demographic data and all the outcome measurements. Pearson correlation coefficients were used for correlation analysis.

Results: No statistically significant differences were found between the two groups in any outcome of the standing balance (P ≥ 0.095) or walking balance (P ≥ 0.160). However, medium effect sizes were found for the UPST (η²: ≥0.06), Challenge Disc (η²: 0.06), TUG (Cohen’s d: 0.54) and COP deviation (Cohen’s d: 0.53). There was a moderate correlation between BMI and Challenge Disc (P = 0.025) and between age and Challenge Disc (P = 0.012) in both the groups.

Conclusion: Patients with chronic shoulder pain had lower balance measurements compared with healthy people, although this difference was not statistically significant.

Keywords: Balance ability, pain, postural stability, sensorimotor system, shoulder

INTRODUCTION

Musculoskeletal pain can affect muscles, tendons, ligaments and bones, can present at localized, regional or widespread areas,¹ and may result in physical, functional and psychological impairments.² It is the fourth leading cause of years lived with disability according to the 2010 Global Burden of Disease study, with a global point prevalence.

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of 8%.[3] Shoulder pain, which is the fourth most common musculoskeletal condition after lower back, knee and neck pain,[2,4] can have a significant effect on a person’s quality of life and activities of daily living.[2]

Body control can be achieved by the information provided from somatosensory, visual and vestibular input. Somatosensation encompasses all the mechanoreceptive, thermoreceptive and pain information arising from the periphery. Proprioception describes afferent information that contributes to postural control (balance), joint stability (segmental posture) and conscious peripheral sensations (muscle senses).[3] Postural balance can be altered by pain.

Research has demonstrated that both chronicity and severity of musculoskeletal pain in the upper and lower quadrant are crucial risk factors for falls.[6,7] For example, neck pain was associated with significant changes in standing balance,[8] and severe low back pain increased the risk of falling.[8] In addition, motor control can be negatively affected by pain in the lower limbs and spine, which can alter proprioception in affected areas.[9] A somatosensory dysfunction in one area of the body can be the cause of shoulder proprioception deficit.[10] Pain may cause balance disorders, as pain processing, balance control circuit, muscle inhibition caused by pain and changes of the proprioceptive feedback in painful structures share the same pathways of the central nervous system. Shoulder pain may alter these pathways, consequently impacting the overall balance/postural control.[11]

To the best of the authors’ knowledge, only one trial has examined balance in patients with shoulder pain. Baierle et al.[11] measured postural stability, balance ability and symmetry index using the S3-Check system. They found that patients with shoulder pain had balance and posture deficits compared with healthy control participants. These authors investigated balance during standing but not while walking. Balance while walking is important in terms of maintaining independence and safety.[12] In addition, balance disturbance may affect the functional capability of individuals.[13] Owing to the paucity of knowledge in this domain, the primary aim of the current study was to investigate balance both while standing and walking in patients with chronic shoulder pain. Our hypothesis was that the patients with shoulder pain would have deficits in standing and walking balance compared with healthy participants. The secondary aim was to determine any possible relationship between outcome measures of standing/walking balance and age and body mass index (BMI). The results of this study may provide additional insights into the examination and treatment of patients with chronic shoulder pain.

**MATERIALS AND METHODS**

**Design and setting**
This is a case–control study that was conducted at the Physical Therapy Department in Dammam Medical Complex, Dammam, Saudi Arabia, from March to November 2018. The study was approved by the institutional review boards at Imam Abdulrahman Bin Faisal University and Dammam Medical Complex. The study followed ethical principles required for human research in accordance with the Declaration of Helsinki, 2013. The manuscript was prepared considering the Strengthening the Reporting of Observational Studies in Epidemiology guidelines. The study participants comprised two groups: a chronic shoulder pain group and a control group.

**Sample size calculation**
The sample size was calculated using G*Power 3.1.9.4 (Franz Faul, Universität Kiel, Germany) based on stability index data from a previous study[11] with the following combination: one-tailed t-test for difference between two independent means; estimated mean 1 of 55,000 with standard deviation (SD) of 6000 and mean 2 of 48,500 with SD of 7125; effect size of 0.99; alpha level (α) of 0.05; power (1–β) of 80%; and allocation ratio N2/N1 of 1. The sample size calculation resulted in 14 participants per group. An extra 10% was added to each group in case of dropouts, resulting in a total of 15 participants per group.

**Participants**
Patients with unilateral shoulder pain were enrolled if they were 25–60 years of age, had pain for 4 months or longer, had pain intensity of 5 or greater on the Numeric Pain Rating Scale within the past week of screening, complained of pain at rest during the study session,[11] and were able to walk independently without aids or assistive devices.[14] Patients with any of the following were excluded from this study: history of major surgery in the lower limbs, trauma to the lower limbs in the past 6 months that affected function, pain in the spine or lower limbs during the study session, neurological diseases, any type of headache during the study, cardiovascular diseases, acute and chronic dizziness, diseases of the inner ear, disorders of the peripheral circulation such as claudication,[14] balance training in the past 6 months and recent use of any medication that affects the central nervous system.[11] Age-, gender- and BMI-matched participants were recruited to the control group. Convenience sampling was applied to recruit the participants.
Outcome measures

Standing balance

The Challenge Disc 2.0 (MFT, TST Trendsport, Grosshöflein, Austria), a primary outcome, is a device with a multiaxial electrical platform that includes motion sensors and with a Bluetooth module, facilitates wireless communication with a smartphone over an application. The installed application has an option to assess the degree of standing balance. The device gives a score of up to 5, with a lower score indicating better balance. This device is valid and demonstrated moderate reliability (intraclass correlation coefficient [ICC]: 0.688) to assess standing balance [Figure 1a].[^15] No established minimal detectable change (MDC) value for the Challenge Disc has been found in the literature. The primary investigator stood in front of the participant to hold the smartphone screen that shows the results. The participant stood on the disc barefooted to avoid the effect of shoe types on the results.[^14] Then, the test started with a 10-s preparation instruction, followed by standing for 20 s with both legs in the center of the disc and arms by their sides while holding their balance. The device provided constant feedback to keep the ball in the center, as steady as possible [Figure 1b]. The device has an anti-slip coating surface that provides necessary safety. The test was stopped if there is a loss of balance.[^15] The test was performed three times, and the mean was used for analysis.

The timed unipedal stance test (UPST) (also referred to as the unipeded balance test or one-leg standing balance) is a valid test of balance and has excellent inter-rater reliability for eyes open (ICC: 0.994) and eyes closed (ICC: 0.998).[^17] The MDC ranged from 5.5 to 16 s.[^18] Decreased time of UPST indicates a decrease in balance.[^19] The participant was instructed to stand on the tested leg (barefooted) and to place the arms across the chest with the hands touching their shoulders and the lower limbs not touching each other. Then, the participant was asked to look forward with their eyes open and concentrate on an object approximately 3 feet in front of them. A digital stopwatch was used to time the test. The test was stopped at a maximum of 60 s or as soon as the limbs touched each other, the feet moved on the floor due to severe balance disturbance, the lifted foot touched the floor or the upper limbs moved from their starting position.[^17] The test was performed once.

The Romberg test was used to assess balance in a standing position. It is highly reliable (ICC: 0.840–0.860) and accurately detects balance dysfunction.[^20] There has been no consensus on the MDC value for the Romberg test, as it is more of qualitative (positive or negative) than quantitative test. The participant was asked to remove their shoes and stand with both feet together. The arms were held next to the body. Then, the primary investigator asked the participant to stand quietly with eyes open and then with eyes closed. The participant tried to maintain balance. The Romberg test was scored by calculating the seconds of standing with eyes closed. The test was considered positive if the participant was unable to maintain balance with the eyes closed for at least 60 s.[^21] The test was performed once.

All the aforementioned measures of standing balance were used for the same construct (standing balance) because they probably assess different balance systems using eyes open (UPST) and closed (Romberg test) and visual feedback (Challenge Disc) with different floor stability.

Walking balance

Center of pressure (COP) mediolateral deviation,[^22] a primary outcome and stance phase duration[^23] were used to test walking balance using the Tekscan MatScan system (Tekscan, Mobile Mat, EH-2 Boston, MA, USA). Stance phase duration is the time elapsed between touchdown and liftoff of the same foot in a gait cycle.[^23] Stance phase duration test has a moderate reliability (ICC: 0.56–0.74) and an MDC value of 0.018–0.028 s.[^24]

The COP mediolateral deviation was calculated by the system, taking the maximum sway of the COP from a straight line that connects the first and last points of a curve. This test has a good reliability (ICC: 0.70) and root mean square error of 0.56 cm.[^25] The participant was instructed to be barefooted to avoid the effect of shoe types on the results.[^26] Then, they practiced determining the appropriate distance that requires walking for three steps, during which the third step strikes the mat until it is completely clear of the mat. With the predetermined starting place, the participant walked at a comfortable speed and focused on a picture on the front wall to ensure that
the gait was as normal as possible. Three measurements were recorded, and the mean of the three measurements was used for analysis.\textsuperscript{26}

The timed up and go (TUG) test is a test for basic functional mobility (walking).\textsuperscript{27} It is a valid and moderately reliable (ICC: 0.510–0.780) tool to screen balance deficiency that may increase the risk of fall.\textsuperscript{28} The MDC value has not been established in the risk of falls or in disorders affecting the upper quadrant. However, the MDC value for lower quadrant musculoskeletal conditions such as hip and knee osteoarthritis is 2.49 s.\textsuperscript{29} The participant stood on the investigator’s command from a chair with armrests, walked 3 meters and returned to the chair and sat down. The time in seconds was measured at the end of the task as soon as the participant sat on the chair. The test was performed three times, and the mean of the three trials was used for analysis.

**Procedure**

At the outpatient rehabilitation clinic in Dammam Medical Complex, patients who were diagnosed with musculoskeletal shoulder pain were referred for our study. The control participants, who fulfilled the inclusion and matching criteria, were invited by personal communication from the hospital staff, friends and family. If the participant agreed to participate, a written consent form was obtained. The primary investigator screened each participant for eligibility. Once eligible, this investigator explained the study to the patient. Initially, demographic data were collected. Then, the outcome measures were tested in the following order: TUG, Romberg test, UPST, Challenge Disc, stance phase duration and COP deviation. This order was standardized for all participants to minimize any possible effect of a test on another. The testing procedure took approximately 1 h.

**Statistical analysis**

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) software for Windows (IBM SPSS version 20.0, New York, NY, USA). Means and SDs were calculated as descriptive statistics for quantitative variables. The Shapiro–Wilk test was used to evaluate the normality of data distribution. To investigate the differences between the two groups, independent \textit{t}-tests were used for normally distributed data, whereas Mann–Whitney \textit{U}-tests were performed for ordinal data and nonnormally distributed data. Chi-square tests were used for categorical data. In addition to the mean difference and 95% confidence interval (CI), Cohen’s \(d\) and \(\eta^2\) were calculated as another parameter for effect size on data from independent \(t\)-tests and Mann–Whitney test, respectively. The ranges of effect size using Cohen’s \(d\) were 0.20–0.49 (small), 0.50–0.79 (medium) and \(\geq0.80\) (large), whereas the ranges for \(\eta^2\) were 0.01–0.05 (small), 0.06–0.13 (medium) and \(\geq0.14\) (large).\textsuperscript{[30]} The criterion for statistical significance was set at \(P < 0.05\), with a 95% CI. Pearson correlation coefficient was used to find the correlation between BMI and age and these measurements with the two groups’ data pooled together.

**RESULTS**

A total of 47 patients were screened for eligibility. Thirty-one patients did not fulfill the inclusion criteria and one patient refused to continue before data collection commenced. Twenty-four healthy participants were screened for the control group; nine of them did not meet the matching criteria. There were no statistically significant differences in the demographic data between the shoulder pathology group and the control group [Table 1]. A total of 15 patients had the following shoulder pathologies: adhesive capsulitis (\(n = 4\)), rotator cuff tendonitis (6), fracture of humerus (2), superior labral tear from anterior to posterior (SLAP lesion) (1), avascular necrosis (1) and dislocation (1).

No significant differences were found in any outcome of the standing and walking balance between the shoulder pain group and the control group. These differences did not reach the MDC for all outcome measures. However, there were trends that both standing and walking balance is lower in the shoulder pain group compared to the control group. This was demonstrated by the medium effect size for UPST (\(\eta^2 = 0.06–0.09\)), Challenge Disc (\(\eta^2 = 0.09\)), TUG (Cohen’s \(d = 0.54\)) and right COP deviation (Cohen’s \(d = 0.53\)) [Table 2].

The Pearson correlation coefficients found statistically moderate negative correlations between BMI and the TUG test (\(r = -0.424, P = 0.020\)), between BMI and the Challenge Disc test (\(r = -0.408, P = 0.025\)) and between age and the Challenge Disc test (\(r = -0.453, P = 0.012\)) in both the groups. These findings indicate that the higher the BMI and age, the more disturbance in balance [Table 3].

**DISCUSSION**

This study did not identify any statistically significant differences in the walking and standing balance between healthy individuals and patients with chronic shoulder pain. However, there were some trends that both standing and walking balance was lower in those with shoulder pain, as demonstrated by medium effect sizes. In both the groups, there were statistically moderate negative correlations...
Table 1: Demographic data of both groups at baseline

| Variables                      | Shoulder pain group (n=15) | Control group (n=15) | Mean/mean rank difference | 95% CI | Significance (statistic; P) |
|--------------------------------|-----------------------------|----------------------|---------------------------|--------|----------------------------|
| Age (years)*                  | 43.7±11.1                   | 43.4±10.3            | 0.27                      | −7.8-8.3 | t=0.070; 0.945             |
| BMI (kg/m²)                   | 27.3 (26.1-27.4)            | 27.4 (24.7-30.8)     | −0.4                      | −2.7-2.7 | U=109.5; 0.901             |
| Occupation (clerk/others)     | 7/8                         | 9/6                  | -                         |        | Chi-square test=0.536; 0.464 |
| Sports                        | 6                           | 5                    | -                         |        | Chi-square test=0.144; 0.705 |
| Diabetics                     | 4                           | 3                    | -                         |        | Chi-square test=0.186; 0.666 |
| Dominance (right/left)        | 13/2                        | 14/1                 | -                         |        | Chi-square test=0.370; 0.543 |
| NPRS during session (cm)      | 2.5±1.4                     | -                    | -                         |        |                             |
| Maximum NPRS last 7 days (cm) | 6.5±0.8                     | -                    | -                         |        |                             |
| Pain duration (months)        | 10.9±6.5                    | -                    | -                         |        |                             |
| Affected shoulder (right/left) | 5/10                        | -                    | -                         |        |                             |
| DASH                          | 40.6±13.3                   | -                    | -                         |        |                             |

*Data are expressed as mean±SD, †Data are expressed as median (IQR), ‡Participants who practice regular exercise ≥2 times per week. BMI – Body mass index; NPRS – Numeric Pain Rating Scale; DASH – Disabilities of the arm, shoulder and hand; †t – Independent t-test; SD – Standard deviation; CI – Confidence interval; IQR – Interquartile range

Table 2: Result of balance during standing and walking

| Variables                      | Shapiro-Wilk test (statistic; P) | Shoulder pain group (n=15) | Control group (n=15) | Between-group differences | Mean/mean rank difference | 95% CI | Cohen's d | Significance (statistic; P) |
|--------------------------------|----------------------------------|-----------------------------|----------------------|---------------------------|---------------------------|--------|-----------|----------------------------|
| Standing balance               |                                  |                             |                      |                           |                           |        |           |                             |
| Challenge Disc (0–5)*           | 0.881; 0.003                     | 4.6 (4.5-4.8)               | 4.6 (4.2-4.7)        | 5.14                      | −0.06-0.39                 | 0.09   | U=74.0; 0.110 |
| Right UPST (s)*                 | 0.729; <0.001                    | 51.0 (34.0-60.0)            | 60.0 (60.0-60.0)     | −4.74                     | −25.20-0.00                | 0.09   | U=77.0; 0.104 |
| Romberg (+−)                   | 0.275; <0.001                    | 2/13                        | 0/15                 |                           |                           |        | Chi-square test=2.14; 0.143 |
| Walking balance                |                                  |                             |                      |                           |                           |        |           |                             |
| Right COPd (cm)†                | 0.976; 0.079                     | 2.71±0.98                   | 3.16±0.88            | 0.44                      | −1.15-0.25                 | 0.53   | t=1-13; 0.201 |
| Left COPd (cm)†                 | 0.972; 0.605                     | 2.34±0.51                   | 2.38±1.05            | 0.04                      | −0.67-0.58                 | 0.05   | t=−1.54; 0.879 |
| Right stance phase duration (s)*| 0.925; 0.037                     | 0.8 (0.8-0.8)               | 0.8 (0.8-0.9)        | −1.86                     | −0.06-0.04                 | 0.01   | U=98.5; 0.561 |
| Left stance phase duration (s)† | 0.986; 0.947                     | 0.80±0.07                   | 0.81±0.07            | 0.00                      | −0.06-0.05                 | 0.10   | t=1.89; P=0.847 |
| TUG (s)†                       | 0.963; 0.374                     | 10.3±0.91                   | 9.81±0.92            | 0.48                      | −0.20-1.16                 | 0.54   | t=1.44; 0.160 |

*Mann-Whitney U-test (U) used and data are expressed as median (IQR), †Independent t-test (t) and data are expressed as mean±SD. †Chi-square test and data are expressed as frequency. COPd – Center of pressure deviation; SD – Standard deviation; TUG – Timed up and go; UPST – Unipedal stance test; CI – Confidence interval; IQR – Interquartile range

Table 3: Relationship between body mass index and age and standing and walking balance

| Outcome measure                  | Shoulder pain group (n=15) | Control group (n=15) | Both groups | Pearson correlation (r) | P |
|----------------------------------|-----------------------------|----------------------|-------------|-------------------------|---|
|                                 | Should pain group (n=15)    | Control group (n=15) | Both groups |                          |   |
| BMIversus                        | 0.070                       | 0.675                | −0.408      | 0.805                   | −0.006 | 0.025* |
|                                 | 0.314                       | −0.279               | 0.054       | 0.255                   | 0.314  | 0.777   |
|                                 | −0.091                      | −0.272               | −0.151      | 0.747                   | 0.326  | 0.427   |
|                                 | −0.007                      | −0.506               | −0.234      | 0.981                   | 0.054  | 0.214   |
|                                 | 0.416                       | 0.284                | 0.349       | 0.123                   | 0.305  | 0.059   |
|                                 | 0.310                       | 0.100                | 0.201       | 0.261                   | 0.723  | 0.287   |
|                                 | 0.375                       | 0.505                | −0.424      | 0.169                   | 0.055  | 0.020*  |
| Age versus                      |                            |                      |             |                         |       |
|                                 | −0.590                      | 0.428                | −0.453      | 0.021                   | 0.111  | 0.012*  |
|                                 | −0.240                      | −0.446               | −0.315      | 0.389                   | 0.096  | 0.090   |
|                                 | −0.072                      | −0.020               | −0.039      | 0.798                   | 0.943  | 0.836   |
|                                 | 0.358                       | −0.102               | 0.141       | 0.190                   | 0.717  | 0.457   |
|                                 | −0.078                      | −0.316               | −0.218      | 0.782                   | 0.252  | 0.247   |
|                                 | 0.278                       | 0.114                | 0.196       | 0.316                   | 0.687  | 0.299   |
|                                 | −0.211                      | −0.144               | −0.177      | 0.451                   | 0.609  | 0.350   |
|                                 | 0.375                       | 0.198                | 0.282       | 0.168                   | 0.480  | 0.130   |

*Significant correlation. UPST – Unipedal stance test; TUG – Timed up and go; COPd – Center of pressure deviation; NPRS – Numeric Pain Rating Scale; BMI – Body mass index

between BMI and the TUG test, between BMI and the Challenge Disc test and between age and the Challenge Disc test. Standing balance was affected in patients with chronic shoulder pain compared with the controls in a previous study.[11] This effect of pain on balance may be explained
by the fact that balance control and pain processing are both controlled by the same central nervous system pathways.\cite{31,32} If a patient experiences shoulder pain, an indirect effect on balance may occur as a result of the pain influencing the central system pathways shared between pain processing and balance control. This explanation of the effect of pain on body control was discussed for cases of low back pain.\cite{33}

Our participants did not show any differences in either standing or walking balance, which disagreed with the findings of Baierle et al.,\cite{11} who examined the standing balance but not the walking balance. A possible explanation for this difference between the studies may be because, in their study, the patients were asked to hold their balance without receiving any visual feedback from the monitor, whereas the patients in our study were looking at the feedback screen to maintain their balance. It should be noted that the outcome measures of standing balance differed in both studies, which provides another explanation for the difference. Body balance is maintained by collaborative action of the visual, vestibular and somatosensory systems. Any deficiency in one of these systems is compensated for by the other systems. In our study, some or all these systems were not ruled out.

A negative correlation between BMI and the Challenge Disc for standing balance and between BMI and the TUG test for walking balance was demonstrated in our study, in agreement with a previous study.\cite{34} In addition, our results found a negative correlation between age and standing balance as measured by the Challenge Disc, which was supported by the findings of another study.\cite{35} Although the likelihood of falls and balance impairment are more common in the elderly, particularly over the age of 65, postural control and balance can also be negatively affected in middle-aged adults aged <65 years.\cite{36}

**Study strengths and limitations**

The results of this study are reasonably valid, as a narrow inclusion criterion was used and an appropriate sample size was estimated before the start of the study. A limitation of the current study was that the researcher was not blinded to the tests or study groups, which could possibly have resulted in bias. Another limitation is that all the participants were men; nonetheless, Hageman et al.\cite{37} had not found differences in balance between male and female patients in different age groups. The Romberg test and UPST test were only performed once, as previous research has not clarified the number of trials required for this test.\cite{38,39} The UPST was also performed once, but this was because a previous study found higher ICC for one trial (0.994 for eyes open and 0.994 for eyes closed) compared with the mean of three trials (0.951 for eyes open and 0.832 for eyes closed).\cite{40} The wide variation in shoulder pathology within the patient group might have affected the study results. The exploratory nature of research may have disadvantages such as difficulty of accurate interpretation of the results for a generalized population. However, this study was carried out because the topic needs to be understood in depth, especially that it has not been studied sufficiently before.

**CONCLUSION**

Our study showed that patients with mild-to-moderate chronic shoulder pain did not demonstrate statistically significant differences in standing and walking balance compared with healthy controls. However, there were trends that balance was lower in the shoulder pain group, as demonstrated by medium effect sizes for some standing and walking balance outcomes. In addition, negative correlations were found between BMI and the Challenge Disc of standing balance and between age and the Challenge Disc in both the groups. Thus, testing balance should be justified in the rehabilitation program for this group of patients. Future research may consider blinding the examiner to the test measurements and the inclusion of patients with high scores of pain intensity and functional disabilities.

**Ethical statement**

The study protocol was approved by the institutional review boards at Imam Abdulrahman Bin Faisal University (Ref no.: IRB-IRB‑2017‑03‑182; date: October 1, 2017) and Dammam Medical Complex (Ref no.: RAC-034; March 19, 2018). The study followed ethical principles required for human research in accordance with the Declaration of Helsinki, 2013. A written informed consent was obtained from each patient.

**Peer review**

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**Conflicts of interest**

There are no conflicts of interest.

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