Osteoarthritis and Cartilage 25 (2017) 42–45

Osteoarthritis and Cartilage

OSTEOARTHRITIS RESEARCH SOCIETY INTERNATIONAL

Brief Report

Standing balance post total knee arthroplasty: sensitivity to change analysis from four to twelve weeks in 466 patients

R.A. Clark †*, F.J.-T. Seah ‡, H.-C. Chong ‡, C.L.-L. Poon ‡, J.W.-M. Tan ‡, B.F. Mentiplay †, Y.-H. Pua ‡

† *School of Health and Sports Science, University of the Sunshine Coast, Australia*
‡ *Department of Physiotherapy, Singapore General Hospital, Singapore*

ARTICLE INFO

Article history:
Received 21 January 2016
Accepted 20 August 2016

Keywords:
Standing balance
Total knee replacement
Posturography
Rehabilitation
Wii Balance Board

SUMMARY

Objective: Little is known about how static standing balance changes post total knee arthroplasty (TKA). The primary aim of this study was to examine the sensitivity to change and redundancy of center of pressure (COP) variables post-TKA. The secondary aim was to compare the sensitivity of these measures to standard clinical assessments of one repetition maximum knee extension strength and fast pace gait speed.
Design: 466 participants performed instrumented double-limb standing balance tests with eyes open at 4 and 12 weeks post-TKA. Measures of COP standard deviation, amplitude, root mean square (RMS), path length, detrended fluctuation analysis (DFA) and signal frequency content for the medial-lateral (ML) and anterior-posterior (AP) axes were examined.
Results: Significant decreases in total path length, ML variables related to sway velocity and AP signal complexity and frequency were observed. Inter-session Cohen's d effect size (ES) revealed the strongest effect was for high velocity ML path length, with a 12% decrease in this rapid sway. This variable, along with AP mean instantaneous frequency and AP DFA, were the only ones significantly different with effect sizes >0.20 and non-redundant (Spearman's rho <0.75). The ES of COP-derived variables (maximum = 0.45) were lower than gait speed (1.40) and knee extensor strength (1.54).
Conclusion: Increased high velocity ML sway is present at four compared to 12 weeks post-TKA. This augmented rapid sway may provide increased challenges to the postural control system at a time coinciding with reduced strength levels, which could have implications for physical function during activities of daily living.

Introduction

Numerous studies have examined changes in physical function after total knee arthroplasty (TKA) using clinical measures of gait, and to a lesser extent balance[1,2]. However, at present there is little knowledge of how static standing balance measured using center of pressure (COP) collected from computerised posturography changes in this post-operative time period[2,3]. For example, one study with a small sample size ($n = 10$) reported that, for most static balance measures derived from COP, balance improved from 17–20 to 34–41 days post TKA but was still impaired relative to a healthy control group. This provides evidence that instrumented two legged standing balance could be a useful assessment tool in the early post-operative stages of rehabilitation from TKA. However, COP can be analysed with techniques ranging from simple methods to quantify maximum sway displacement, such as peak amplitude, through to mathematically complex methods quantifying signal chaos, such as detrended fluctuation analysis (DFA). Consequently, the sensitivity to change over time and redundancy of potential outcome variables must be established before a variable is selected as a primary clinical outcome measure.

The primary aim of this study was to examine the sensitivity to change and redundancy of outcome variables derived using a low-cost computerised posturography system, the Nintendo Wii Balance Board (WBB), from 4 to 12 weeks post TKA. A secondary aim was to compare the sensitivity of these measures to commonly

* Address correspondence and reprint requests to: R.A. Clark, Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Sippy Downs, QLD 4556, Australia.
E-mail address: rclark@usc.edu.au (R.A. Clark).

http://dx.doi.org/10.1016/j.joca.2016.08.009
1063-4584/

performed clinical assessments of gait speed and muscle strength. We hypothesize that the majority of balance measures will significantly improve over time, however they will not be as sensitive to change as gait speed or knee extensor strength.

Methods

Data from 466 participants (age: 67 ± 7 yrs, height: 157 ± 8 cm, body mass: 67 ± 12 kg) who had undergone a primary, unilateral TKA at a major metropolitan hospital to alleviate pain symptoms from knee osteoarthritis between July 2013 and May 2015 is reported. Participants were attending monthly, standard practice, post-operative and post-discharge physiotherapy rehabilitation at the hospital which was not standardized in terms of treatment content. These participants were extracted from a total pool of 4114 patients attending this service during this time period who performed identical balance assessments as part of routine practice. The participants in this study were selected as they performed identical computerised posturography assessments within ±2 weeks of both 4 and 12 weeks post-operative. In addition to the time constraints, participants from the larger cohort were excluded if they had a diagnosed neurological condition, rheumatoid arthritis or any other condition which was likely to affect balance differently between time points. This sample size was chosen as it exceeded the minimum number of participants ($n = 394$) to achieve statistical significance between time points using two-tailed *t*-tests with a small effect size (Cohen's d = 0.2) and a power of 0.8.

Computerised posturography was performed using a WBB and customised software calibrated in accordance with Clark *et al.*[4] The individual sensors of the WBB were sampled and filtered individually, converted to COP and interpolated to 100 Hz, and lowpass filtered at 6.25 Hz using a three-level undecimated Symlet-8 wavelet with the detail levels removed[5].

All participants performed two 30-second trials of quiet standing with their eyes open with a one-minute rest interval, and the mean of two valid trials was recorded. Tests were performed in a treatment room with the curtains closed, and although background noise in a hospital cannot be readily controlled no speaking by or to the patient was allowed during data collection. Standing balance tests were performed with the patient's feet in their self-selected comfortable stance and looking at a spot directly in front of them on the wall. After careful consideration prior to the start of data collection we chose not to standardise the foot position for a number of reasons. These included (1) we did not want factors such as pain to confound the results of the initial balance assessment, and (2) we wanted the standing balance test to reflect the individual's natural standing position at the time of testing, not a fixed position which may become more or less comfortable throughout the recovery process. We chose an eyes open test because of its clinical utility, and because it has been previously reported to show improvements early post-TKA[3].

To provide a population-specific perspective to the strength of the observed effect sizes (ES), the sensitivity to change of fast-paced gait speed and knee extensor strength were also examined. Patients walked a total of 14 m, with the time recorded by the clinician using a stopwatch from the instant the first foot crossed the 2 m line until the lead foot crossed the 12 m line to remove acceleration/deceleration from the result. Patients were instructed to “walk as quickly as you can, but safely”. Each patient performed a familiarization trial before the actual trial, which is reported in meters/second. Knee extensor strength in kilograms was examined using a seated knee extension machine (Cybex VR3, Medway, USA) as described previously[6]. The patient sat on the chair of the machine with a trunk-thigh angle of 90°. The shin pad was positioned just proximal to the ankle joint center, and knee range-of-motion was restricted from 90° to 40° of knee flexion to avoid the increased patellofemoral joint stress associated with terminal knee extension during open chain movements[7]. Knee extension strength was determined using the isotonic one repetition maximum (1RM) test, which identifies the heaviest load that can be lifted for one full repetition. We performed a familiarization trial on the contralateral (non-TKA) knee before the ipsilateral (TKA) knee to ensure the participant understood the test requirements. Thirty-second rest periods were allocated between attempts, and most patients reached their one repetition maximum between the third and fifth trials after beginning the trial with a comfortable load.

Data analysis

To determine which COP measures were sensitive to change we examined a variety of outcome variables (described in detail in the Supplementary material). These were:

1) Total and independent axis COP path length, which is simply the total distance (cm) that the COP trace moves during the trial.
2) Peak COP displacement amplitude (cm) on the ML and AP axis. Higher amplitudes indicate greater sway range of motion.
3) Standard deviation (SD) of the COP trace (cm) on each axis. A higher value indicates greater exploration about the centre position.
4) Root mean square (RMS) amplitude (cm) and velocity (cm/s) on each axis. This quantifies the average absolute distance of the COP from the starting position throughout the trial.
5) High and low velocity COP path length (cm) for each axis using wavelet analysis. This technique has been used previously[8–10], with these two bands shown to be non-redundant and sensitive to clinical conditions or task demands[9,11].
6) DFA on each axis (alpha). DFA is a fractal measure that categorises the long range correlations in a signal to provide a measure of signal complexity and persistence, and has been described previously as a means of characterising posturographic data containing rapid corrective impulses[12]. DFA was calculated for small box sizes between 32 and 100 (DFA A1) and larger box sizes above 100 (DFA A2), and for both the displacement trace and its first derivative (velocity) independently.

An example of this data analysis software, and how it interfaces with an albeit uncalibrated WBB, is freely available at the website www.rehabtools.org.

Statistical analysis

Sensitivity was expressed as change over time for each of the outcome measures, and was assessed using paired samples *t*-tests at alpha level 0.05. Cohen's d ES, with correction for within-group analysis by including the correlation between scores at the two time points in the equation[13], were calculated for each variable. Thresholds were set at 0.2 for small, 0.5 for moderate and 0.8 for large effects[14]. Spearman's correlation was performed on four week data between variables that were significantly different and possessed ES > 0.20 inter-session to assess redundancy, with a threshold of >0.75[15].

Results

Patient characteristics, gait speed, knee extensor strength and balance results are provided in Table I. The percentage change for the balance variables is shown graphically in Fig. 1. Statistically significant differences were observed for the majority of outcome measures. However, only 6/26 of the posturography variables had