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Technical and measurement report

Does repeated palpation-digitization of pelvic landmarks for measurement of innominate motion introduce a systematic error? – A psychometric investigation

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ABSTRACT

Background: Palpation-digitization technique for measurement of innominate motion involves repeated manual palpation-digitization of pelvic landmarks, which could introduce a systematic variation between subsequent trials and thereby influence final innominate angular measurement.
Objectives: The aim of this study is to quantify the effect of repeated palpation-digitization errors on overall variability of innominate vector length measurements; and to determine if there is a systematic variation between subsequent repeated trials.
Method: A single group repeated measures study, using four testers and fourteen healthy participants, was conducted. Four pelvic landmarks, left and right posterior superior iliac spine and anterior superior iliac spine, were palpated and digitized using 3D digitizing stylus of Polhemus electromagnetic tracking device, for ten consecutive trials by each tester in their random order. The ten individual trials of innominate vector lengths measured by each tester for each participant were used for the analysis.
Results and conclusions: Repeated measures ANOVA demonstrated a very small effect of repeated trial factor ($\leq$0.66%) as well as error component ($\leq$0.32%) on innominate vector length variability. Further, residual versus order plots demonstrated a random pattern of errors across zero; thus indicating no systematic variation between subsequent trials of innominate vector length measurements.

1. Introduction

Electromagnetic palpation-digitization of pelvic landmarks is a radiologically validated procedure, with high levels of reliability for accurate measurement of innominate movements, in healthy as well as symptomatic individuals (Bussey et al., 2004, 2009a, 2009b; Bussey and Milosavljevic, 2013; Adhia et al., 2012, 2015). This technique involves repeated manual palpation-digitization of two pelvic landmarks, namely anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS), followed by calculation of innominate vector lengths (IVL) between these palpable landmarks using their digitized 3D coordinates. The average of repeated trials of IVL is then used to obtain innominate angular measurements. While use of average measures reduces random error, manual palpation-digitization of pelvic landmarks is highly dependent upon tester characteristics such as experience, palpation skills and technique, and its repeated nature could hypothetically introduce a systematic variation between repeated trials (Field, 2009). Such systematic change could result in significant differences between subsequent trials and averaging these significantly different trials could largely influence the final innominate angular measurement. The aims of this study are therefore to quantify the effect of repeated palpation-digitization trials of pelvic landmarks and to determine the effect of error on overall variability of IVL measurements; as well as to determine if there is a systematic variation between subsequent repeated trials of IVL measurement. We hypothesise that the repeated trials factor will have a minimal effect on IVL measurement and there will be no systematic variation between subsequent repeated trials.

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2. Methods

2.1. Study design and participants

A single-group, repeated measures design, using four independent testers and fourteen healthy individuals was conducted. Any potential participants with a current/past history of low back/hip disorders, lumbar/sacral nerve root compromise, lower extremity disorders, known spinal pathology, spinal surgery, or pregnant, were excluded. Ethical approval was obtained from the School of Physiotherapy Human Ethics Committee, University of Otago, New Zealand.

2.2. Instrumentation

A standardised table (Bussey et al., 2004) was used to position the participant in prone lying. Kinematic data were collected using Polhemus Liberty™ (Colchester, VT, US) electromagnetic tracking device. The global system of electromagnetic tracking device, mounted to the standardised table, was transformed to local reference sensor, attached to skin over 3rd lumbar spinous process of each participant. The static accuracy of local reference system for measurement of position between two sensors was 0.015 mm (Adhia et al., 2012).

2.3. Testers and training

A convenience sample of four musculoskeletal physiotherapists with varying levels of clinical experience (1yr−10yrs) were recruited for this study. A researcher with expertise in palpation-digitization of pelvic landmarks provided familiarization and training to the testers for 2 one-hour sessions. Based on the consensus among expert and testers, the palpation technique was standardized to palpating and identifying the highest point of iliac crest followed by tracing this landmark posteriorly and anteriorly to reach the highest prominence of PSIS and ASIS respectively; which was then digitized using the digitizing stylus of electromagnetic tracking system. The order of the four testers was randomized and each tester was blinded to the measurements taken by other tester.

2.4. Procedure

Following written informed consent, each participant attended a three hour testing session. Demographic and anthropometric data were gathered. All participants were positioned in prone-lying on standardised testing table. Each tester independently performed the same test procedure in their random order. The test procedure involved palpating and identifying four pelvic landmarks, namely the right PSIS, right ASIS, left PSIS and left ASIS in that order. The most prominent part of each palpated landmark was digitized using the 3D digitizing stylus. Each pelvic landmark was repeatedly palpated and digitized by each tester independently for ten consecutive trials.

2.5. Data reduction

The 3D spatial coordinates for each pelvic landmark with respect to the local coordinate system were obtained from proprietary written computer software.[2] Four pelvic landmark vectors (V_{OA}, V_{OB}, V_{OC}, and V_{OD}) originating from local sensor L3 (O) and pointing to each pelvic landmark (left PSIS: A, right PSIS: B, left ASIS: C, right ASIS: D) were defined from the available 3D pelvic coordinates using a transformation matrix embedded in Matlab™. The two IVL (right and left) was defined as difference between the respective ASIS and PSIS vector lengths and was calculated as follows:

$$\textit{Right innominate vector}\ (V_{BD}) = \textit{Right ASIS vector}(V_{OD}) - \textit{Right PSIS vector}(V_{OB})$$

$$\textit{Left innominate vector}(V_{AC}) = \textit{Left ASIS vector}(V_{OC}) - \textit{Left PSIS vector}(V_{OA})$$

(Adhia et al., 2012)

The ten consecutive trials of IVL in the order that they were measured by each tester for each participant were used for analysis.

2.6. Data analysis

A repeated measures analysis of variance (ANOVA), using SPSS version 16.0, was conducted individually for IVL of each side and for each tester. The total variability [Mean squares, total (MS_T)] was partitioned into between-participant variability [Mean squares, between-participant (MS_B)] and within-participant variability [Mean squares, within-participant (MS_W)]. The within-participant variability (MS_W) was further partitioned into repeated-trials effect [Mean squares, model (MS_M)] and error component [Mean squares, residuals (MS_R)]. The percentage mean squares (MS_B%, MS_W%, MS_M%, MS_R%) were calculated to interpret how much the within-participant variability contributed to the total variability, and how much the MS_M (repeated-trials effect) and MS_R (errors) contributed to the within-participant variability. The F-statistic was obtained from repeated measures ANOVA; and the percentage omega-squared (ω^2) values were calculated to interpret the overall effect of repeated palpation-digitization trials on the overall variability of IVL (Field, 2009).

The residuals of IVL for each trial of each participant as measured by each tester were obtained from SPSS. The residuals versus order of data plots (plotted using Microsoft Excel™) were then used to determine systematic variation in IVL measurements from trial-1 through trial-10. These plots were interpreted as follows: non-uniform pattern of residuals across zero as trials increased was defined as the errors (residuals) being independent of order of data (trials), thus indicating no systematic variation across trials; whereas a decreasing trend in residuals as trials increased was defined as the errors being dependent of order of data, thus indicating a systematic variation across trials (tester learning). These analyses were done individually for both IVL (left and right) for each participant as measured by each tester.

3. Results

Fourteen healthy participants had a mean (±SD) age and BMI of 26.50 (±6.59) yrs and 22.12 (±2.33) kg/m^2 respectively. The mean (±SD) right and left IVL ranged between 159.30 (±2.47) mm and 160.22 (±1.81) mm respectively.

Fig. 1 demonstrates how each source of variability contributed to the total variability. The within-participant variability contributed to a very small percentage ($MS_W \leq 3.00\%$) of total variability irrespective of tester or side, thus implicating a very small effect of repeated-trials factor ($MS_M \leq 0.66\%$) and error component ($MS_R \leq 0.32\%$) on IVL measurements. Further, the F-ratio's and a very low effect size ($\omega^2 < 0.30\%$) (Table 1), further implicate a very

[2] The computer software LibCtrl™, connected to the electromagnetic tracking system, was developed by the School of Physical Education, Sport and Exercise Sciences, University of Otago, NZ.