Calibration of an instrumented couch with a motion-capture system in measuring force applied and distance during manual therapy

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Abstract

Objective: This study aimed to (i) describe an instrumented couch which would be able to synchronize with the motion-capture system in details; (ii) calibrate this device in measuring applied forces on its surface and distance.

Study design: The criterion-related validity and test-retest reliability.

Methods: The criterion-related validity and reliability of the couch were investigated in two conditions: empty couch and a couch with dead weight of known mass 70 kg., in three directions (vertical, medial-lateral and caudad-cephalad directions). The motion-capture system was also investigated by using the grid paper size 40×40 cm^2. Pearson's correlation and the intraclass correlation coefficient (2, 1) were used to analyze the validity and the reliability of the couch in measuring the applied force and motion-capture system in measuring the distance. The percentage error was calculated for both the couch and the motion-capture system.

Results: The Pearson's correlation of the couch and the motion-capture system in this study was 1.00 ($p<0.05$). The intraclass correlation coefficient (2, 1) of the couch was 1.00 ($p<0.05$). The average percentage error of the couch in measuring the applied force and the motion-capture system in measuring the distance ranged from 0.41-1.12% and 0%, respectively.

Conclusion: The instrumented couch and the motion-capture system are appropriate to investigate both amount of force applied and displacement during manual therapy.

Keywords: Instrumented Couch, Manual Therapy, Forces Applied

การปรับเทียบเตียงพร้อมอุปกรณ์วัดแรงและระบบบันทึกการเคลื่อนไหว ในการวัดแรงและระยะทาง ขณะทำการรักษาด้วยมือ

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บทคัดย่อ

วัตถุประสงค์: เพื่ออธิบายการทำงานของเตียงพร้อมอุปกรณ์วัดแรงพร้อมระบบบันทึกการเคลื่อนไหว และทำการสอบเทียบหาความเที่ยงตรง และความน่าเชื่อถือของเครื่องมือที่ประยุกต์ขึ้นมา

วิธีดำเนินการวิจัย: ค่าความเที่ยงตรงและความน่าเชื่อถือของเตียงพร้อมอุปกรณ์วัดแรงจะถูกประเมินใน 2 เงื่อนไข คือ การทดสอบบนเตียงเปล่า และการทดสอบขณะมีน้ำหนัก 70 กิโลกรัมวางบนเตียง โดยทำการทดสอบทั้ง 2 เงื่อนไขใน 3 แกน คือ แกนตั้ง แกนนอนตามขวาง และแกนนอนตามยาว ในกรณีของการสอบเทียบระบบบันทึกการเคลื่อนไหว ทำโดยใช้กระดาษตารางขนาด 40 × 40 เซนติเมตร^2 ความเที่ยงตรงของเตียงพร้อมอุปกรณ์วัดแรงและระบบบันทึกการเคลื่อนไหว ถูกวิเคราะห์โดยการคำนวณหาค่าสัมประสิทธิ์สหสัมพันธ์เพียร์สัน ความน่าเชื่อถือของเตียงพร้อมอุปกรณ์วัดแรงใช้การคำนวณหาค่าสัมประสิทธิ์สหสัมพันธ์ภายในกลุ่ม [$ICC_{(2, 1)}$] และยังได้นำการคำนวณหาความคลาดเคลื่อนเป็นร้อยละ มาคำนวณทั้ง เตียงพร้อมอุปกรณ์วัดแรงและระบบบันทึกการเคลื่อนไหว

ผลการวิจัย: เตียงพร้อมอุปกรณ์วัดแรงและระบบบันทึกการเคลื่อนไหวมีค่าสัมประสิทธิ์สหสัมพันธ์เพียร์สันเท่ากับ 1.00 ($p<0.05$) ในส่วนของการคำนวณสัมประสิทธิ์สหสัมพันธ์ภายในกลุ่ม [$ICC_{(2, 1)}$] ของเตียงพร้อมอุปกรณ์วัดแรงพบว่ามีค่าเท่ากับ 1.00 ($p<0.05$) ในขณะที่ค่าร้อยละของความคลาดเคลื่อนของเตียงพร้อมอุปกรณ์วัดแรงพบว่ามีค่าเฉลี่ยอยู่ระหว่าง 0.41-1.12 ในกรณีของระบบบันทึกการเคลื่อนไหวพบว่าค่าร้อยละของความคลาดเคลื่อนในการวัดระยะทางเท่ากับ 0

สรุป: เตียงพร้อมอุปกรณ์วัดแรงและระบบบันทึกการเคลื่อนไหวมีความเหมาะสมสำหรับใช้วัดแรงและการเคลื่อนที่ขณะทำการรักษาด้วยมือ

Introduction

Manipulative therapy (MT) is commonly used in the treatment of musculoskeletal disorders. It has been noted that MT was effective in pain reduction known as the neurophysiological mechanism whereas the effect on mobility is still unclear. In order to investigate the effectiveness on mobility, a number of devices were developed such as spinal physiotherapy simulator [1], spinal mobiliser [2], the spinal assessment machine [3], and the spinal posteroanterior mobiliser [4]. Such devices are very useful for researching, unfortunately they are not commercially available and costly. Due to such limitations, a number of devices were therefore developed in order to quantify force applied during MT. These include a flexible pressure pad [5], a force plate [6,7], and instrumented couch [8-10].

Nevertheless, the devices mentioned previously have some disadvantages to be concerned as follows. The use of the flexible pressure pad seems to be the most convenient method. This is because it cannot only be set in clinical practice but also directly quantify the applied force. However, the position of the pad is argued to diminish the therapist's perception of the joint movement being treated[8]. In order to allow the therapist to perceive a joint movement during MT, the force plate was used instead of the pressure pad to quantify the force. The use of this device seems to be somewhat more beneficial than that of the pressure pad. However, the limitations of this device were reported as follows. First, the use of this device is argued to be inappropriate. Second, this device can quantify the force applied only in static setting while the MT is applied dynamically. As a result, a therapist would have to hold the application of force applied for 0.5 to 1 second during the data collection [6,7]. Therefore, the force and time data obtained from the force plate may not represent the real force during MT. Up to present, the couch mounted with load cells has been claimed to reduce the disadvantages mentioned previously, because it can directly measure the force applied and does not interfere the therapist's perception during MT [8-10].

Additionally, there are a number of methods used to investigate spinal displacement occurred during MT. These include X-rays [14], magnetic resonance imaging (MRI) [11-14], and motion analysis [15-17]. Once again, the use of such methods seems to be beneficial to both researchers and practitioner. For example, it provides normative data with regard to spinal displacement and the effect of the forces applied to the adjacent spines. Therefore, there is a clear need to develop a device which would be able to quantify both applied force and distance in order to explain the effect of MT on mechanical properties. The aims of this study were to describe an instrumented couch in measuring applied forces which would be able to synchronize the data with the data from the motion capture system in details and to calibrate this device.

Objectives

This study aimed to (i) describe an instrumented couch which would be able to synchronize with the motion-capture system in details; (ii) calibrate this device in measuring applied forces on its surface and distance.

Methods

A treatment couch (Manumed Optimal 1-section electric H/L type 323, Model no. 5100103, Enraf Nonius Medical Equipment CO., LTD., Netherlands) was used to modify using the similar concept noted in the previous studies [8-10]. Briefly, a treatment couch was modified by mounting seven resistive load cells (Tension S Cell, Mettler Toledo (Thailand) Limited) to the base of the couch frame. The capacity of each load cell in measuring the force is 100 kg. Four, two and one load cells were positioned in the vertical, medial-lateral and caudad-cephalad directions, respectively (Figure 1).

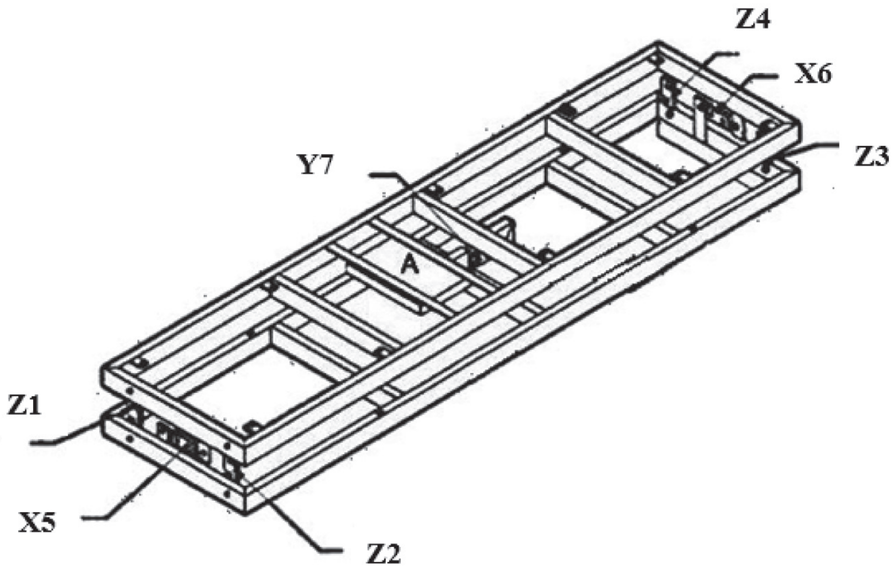

Figure 1: Positions of load cells mounted to the couch frame Z1 to Z4, X5 to X6 and Y7 represent the location of the four load cells in the vertical, two load cells in medial-lateral and one load cells in caudad-cephalad directions, respectively. A represents the amplifier.

All signals from load cells were sent to a custom-made amplifier (Figure 2: A) which was mounted to the couch frame via a high-speed cable. The signals from the amplifier were sent to a display box (Figure 2: C), the box also had a zero-function allowing to set the applied force on the couch as zero. The signals from the display box were sent to a signal translator (Figure 2: D) before sent to the computer (Figure 2: E) and could be saved as a Microsoft excel file for further analysis using the Contemplas templo motion analysis software (GmbH Albert-Eintein-Straße 6 87437 D-Kempten; Germany). The frequency of data sampling would be able to set as from 30 to 1,000 Hertz (Hz).

The two high speed video cameras (Basler scA640, Basler AG An der Strusbek 60-62 D-22926 Ahrensburg, Germany) with tripods were connected to the computer in order to quantify movement occurred during MT (Figure 2: B_1 & B_2). The cameras had resolution of 658×492 pixels with sampling frequency of 71 Hz. The data obtained from the cameras was able to be imported and saved as the Microsoft excel file for further investigation. Once again, the data obtained from the cameras was able to synchronize with the force-time data obtained from the load cells by plotting graph in

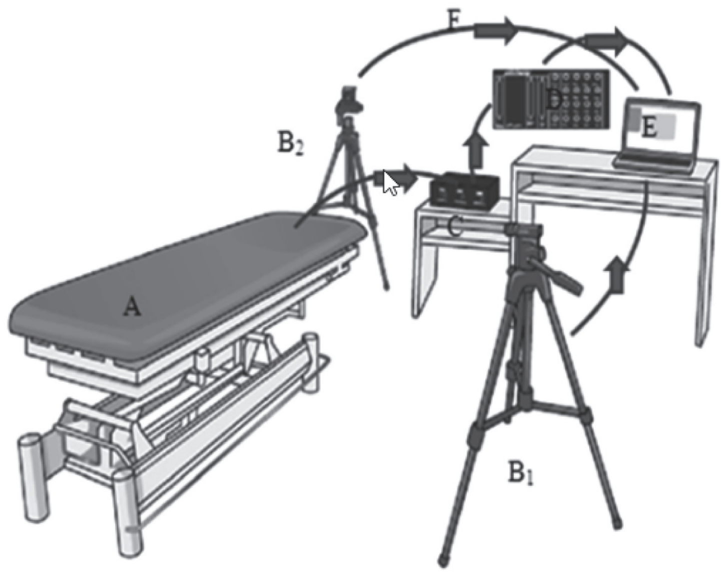

Figure 2: Functional processes of the data obtained from the instrumented couch and two cameras flow to the computer.

the Microsoft excel file.

A to F represent to the instrumented couch, the cameras, display box, signal translator, computer and the high speed cable for sending the data, respectively. The symbol, arrows, showed directions of the data flow from the instrumented couch and two cameras to the computer.

The criterion-related validity and test-retest reliability of the couch were investigated in two different conditions: an empty couch and a couch with dead weight of known mass 70 kg. The weights ranging from 0.5 to 80 kg were used as a gold standard and were placed on the midline of the couch in three different positions (i.e. in the cephalad, middle and caudad) to investigate the criterion-related validity of the couch in the vertical direction. Force readings were undertaken twice with 10 minutes interval in three directions: vertical, medial-lateral and caudad-cephalad directions.

In the medial-lateral and the caudad-cephalad directions, the force reading was undertaken by using a pulley. The pulley was attached to the couch by the hook fastened beneath on the middle of the couch frame in four positions (i.e. in the cephalad, caudad, left and right) to hang the set weight of known mass ranging from 0.5 to 40 kg. The weight was then left for 10 seconds in order to leave it until it was steady, after that the measurement was undertaken. The force reading obtained from the couch and the known mass obtained from the dead weight were kept for analyzing the criterion-related validity. Finally, the measurement would be recorded in three directions in order to investigate the crosstalk during the force measurement. The crosstalk is defined as a phenomenon by which a force reading on one direction creates an undesired effect in the other direction.

The criterion-related validity of the motion capture system was investigated by using a grid paper size 40 × 40 centimeters^2 as a gold standard. The grid paper was attached to a box and then positioned on the couch in order to ensure the grid paper position to be in the vertical direction. The motion capture system was focused on the grid paper and the distance measurement was then taken place. The criterion-related validity of the motion capture system was investigated by correlating the data obtained from the motion capture system to the value obtained from the grid paper using the Pearson's product-moment correlation. The percentage error in measuring the distance was also calculated.

Statistical analysis

The criterion-related validity of the couch in measuring applied forces and the motion capture system in distance readings were investigated by correlating the data obtained from the couch to the gold standard and the data obtained from the motion capture system to the distance on the grid paper using the Pearson's product-moment correlation, respectively. The Pearson's correlation and the Intraclass correlation coefficient ($ICC_{2,1}$) were investigated by using the SPSS program version

17. The percentage error of the couch in measuring the force applied and the motion capture system in measuring the distance were calculated.

Results

The criterion-related validity of the couch in two conditions were very high with the correlation of 1.00 ($p<0.05$). The reliability of the couch was very high with the $ICC_{(2, 1)}$ of 1.00 in all direction ($p<0.05$). The average of percentage errors was less than 1.2% and 0.9% for an empty couch condition and with dead weight of known mass of 70 kg, respectively. The percentage crosstalk was less than 1.03 % in all directions. Also, the criterion-related validity of the motion capture system was very high with Pearson's correlation of 1.00 ($p<0.05$). The percentage error of measurement of 0% was also showed.

Discussions

The results showed high criterion-related validity of the instrumented couch with Pearson's product-moment correlation of 1.00. This finding indicates excellent correlation coefficients with the gold standard [18] . This finding was consistent to the correlation noted in previous studies [8-10]. The percentage errors of this study had been shown to be low and less than those of previous studies [8,9].

The reliability of the couch in measuring the applied force was high which was consistent to the ICCs noted in previous studies [9,10] . The crosstalks noted in the current study were low (ranging 0.19-1.03%) which were good within the range noted in the previous study [12] . It has been suggested that the crosstalk being less than 5% indicates the acceptable the error value [18] . Based on these results, the couch was shown to be a valid and reliable device in quantifying the force applied to its surface.

With regards to the motion capture system, the correction coefficient was very high, and the percentage error of this measurement is 0%. Once again, the motion capture system was a valid device in quantifying the distance from a reference point.

Conclusion

Based on these findings, the instrumented couch and the motion capture system should be appropriate for researching as well as teaching the corrected methods of MT.

Conflicts of interest statement

The author(s) have no conflicts of interest relevant to this article.

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