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Quantifying Joint Mobilizations with The Mobil-Aider™

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Abstract

Background: Millions of musculoskeletal injuries occur each year, which results in pain, swelling, and limitations in joint movement. Joint mobilization techniques aim to restore the accessory movements between joint surfaces. Studies have reported that skilled clinicians have good relative intra-clinician reliability, i.e. they could replicate their "Force" application during joint mobilizations, but had poor to moderate reliability between clinicians. The Mobil-Aider™ is a new device designed to quantify the performance of joint mobilization techniques. This manuscript shares the development process of this novel orthopedic device including bench testing for validity and reliability.

Methods: A Zeiss Smart zoom microscope was used as the gold standard to assess the ability of the Mobil-Aider™ to measure linear translation the primary movement of joint mobilizations. Sixty linear translations were performed with each Mobil-Aider device. Separate readings were recorded from the Mobil-Aider and the Zeiss to determine validity. A total of 60 blinded measures were taken with six different Mobil-Aider devices (total of 360 measures) were performed to assess reliability.

Results: The Pearson correlation were 0.986, indicating a strong correlation between the measures. The Cronbach alpha reliability analysis was 0.992. Independent one-sample t-tests were performed on the differences between the Mobil-Aider™ and the Zeiss values and were not found to be significant ($p = 0.42$). This indicates the measures were not statistically different, i.e. they are the same. Bland Altman plot and a linear regression revealed no propositional bias. Finally, with 360 measures over six devices, the power of this study was calculated to be 100%.

Discussion: The data collected in this study is the first step in establishing reliability and concurrent validity of a new device. As a result of the current data, the Mobil-Aider™ device is deemed a promising orthopedic tool for measuring the linear translation associated with joint mobilizations. The collection of clinical data needs to be the next step.

Keywords: Joint mobilization; Arthrokinematics; Manual therapy

Introduction

Millions of musculoskeletal injuries occur each year resulting in pain, swelling, and limitations in joint movement. Abnormal joint mobility is a component of movement dysfunction [1]. Joint mobilization techniques aim to restore the accessory (Arthrokinematics) movements between joint surfaces [2-4]. Joint mobilizations are known to influence a variety of joint structures [5,1]. Neurophysiologic alteration in the cutaneous receptors, muscle spindles, and mechanoreceptor threshold have been reported to be an explanation for decreased pain, increased mobility, and increased strength after joint mobilization [1,3,5-7]. Likewise, physical loading and unloading of joint cartilage may facilitate the flow of synovial fluid within the joint to enhance nutrition to the articular cartilage [8].

Maitland [9,10] described the passive, oscillatory, rhythmic movements to a joint by grades. There are four grades of mobilization:

- Grade I - small amplitude motions in the first quarter (beginning) of the available joint translation
- Grade II - larger amplitude motions in the first half of the available joint translation, approaching the first onset of resistance (R1)

- Grade III - larger amplitude motions in the second half of available joint translation, into the final onset of resistance (R2)
- Grade IV - small amplitude motions at the last quarter of the available joint translation, into the final onset of resistance (R2)

Grade I and II mobilizations can be used to abate pain [4,9,10]. Whereas, grade III and IV mobilizations can be used to address tissue extensibility [4,5,9,10].

One can appreciate the cognitive elements of joint mobilizations, but unless this knowledge can be transitioned to the psychomotor skill in a clinical setting, it is of little use. Studies have reported that skilled clinicians have good relative intra-clinician reliability, i.e. they could replicate their "Force" application during joint mobilizations, but had poor to moderate reliability between clinicians [11,12]. Due to varying degrees of joint limitations, clinicians could use the same amount of force on two different people and achieve very different quantities of linear translation. To that end, studies have reported a poor correlation between force and displacement [2,13,14]. In addition, the rate of force application may influence the magnitude of displacement [15]. Performance of accurate and consistent joint mobilizations is a critical component of efficacious treatment. With total linear excursion of joints from 5-15 mm, even the seasoned clinician could use help ensuring clinically consistent techniques [11].

The process of acquiring motor skills requires learning, error detection, error correction, and training [16]. More specifically, mastering a psychomotor skill requires purposeful practice with visual feedback [17,2]. Concurrent feedback given while the learning task is in progress is critical [17]. Major organizations such as the American Heart Association (AHA) have recognized this process and implemented changes to employ feedback devices for the performance of cardiopulmonary resuscitation. The 2015 AHA Guidelines state, "Unfortunately, inadequate performance of resuscitation is common yet challenging for providers and instructors to detect, thereby making it difficult to appropriately focus feedback and improve future performance." Studies have shown feedback devices help students achieve mastery of critical resuscitation skills and shorten the time to demonstration of competence. Likewise, the performance of consistent joint mobilizations could be enhanced with concurrent, visual feedback. Gonzalez-Sanchez, et al. [18] demonstrated the effectiveness of real-time feedback among students learning ankle joint mobilizations when compared to traditional teaching methods. Yet, the limited devices available for quantitative feedback of joint mobility are either too cumbersome [19-21] or measure force [2,12,22-24].

In 2016, work began on the development of an innovative device to quantify joint mobility, i.e. arthrokinematic motion. The two challenges were to identify a means to quantify joint translation and develop joint contours to minimize potential interface errors. Since joint mobilizations can require different amounts of force to reach R1 or R2 [13], the decision was made to establish a device to measure linear distance/displacement, i.e. the magnitude of translation of one osseous surface on another, as opposed to force. By placing the Mobil-Aider axis (figure 1 arrow) on the joint line, the device can be stabilized on the proximal side of the joint while the screen-side of the device can mobilize the distal side of the joint, i.e. translating distal on proximal. The measurement is then revealed via a Light-Emitting Diode (LED) display (figure 1). Finding a way to contour the device to an array of body surfaces proved challenging. The lack of direct, contoured contact was one of the issues with a prior device to assess of the anterior/posterior translation of the knee (KT1000/2000).

Figure 1: The Mobil-Aider™ Device.

After studying the contours of the peripheral joints, it appeared that majority of joint mobilization techniques could be accomplished with seven attachments. These attachments could be donned/doffed on the main device via a dovetailed slot with a spring-loaded plunger mechanism. By interfacing the device between the patient's joint and the clinician's hands, the mobilizations could be performed in the traditional manner (minimal learning curve). The seven colorful attachments (figure 2) were fabricated for the following joint glides:

- Red = supine tibiofemoral anterior
- Yellow = talocrural anterior, prone tibiofemoral anterior
- Blue = glenohumeral anterior/posterior, sternoclavicular posterior
- Green = glenohumeral inferior, ulnohumeral medial/lateral, radiocarpal medial/lateral, talocrural posterior, subtalar medial/lateral

- White = radiocarpal dorsal/volar
- Black (large) = supine tibiofemoral anterior stabilization component
- Black (small) = stabilization component for all other mobilizations

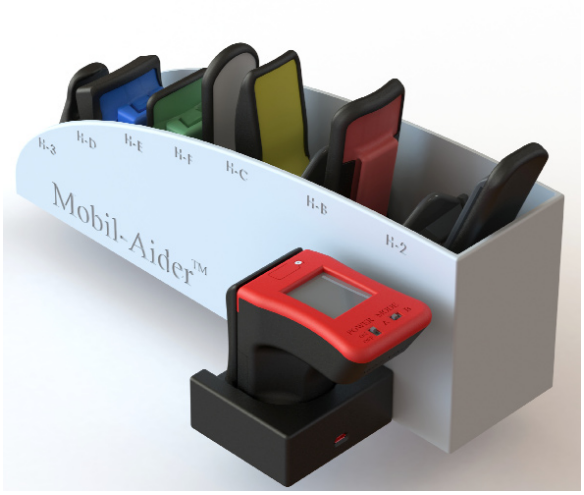

Figure 2: Mobil-Aider™ Docking Stations with Joint Attachments.

The Mobil-Aider™, has been funded, in part, by a National Science Foundation Phase I and Phase II Grants. Throughout the development process, numerous changes were made. Once a minimal viable prototype was created, bench testing was performed and clinical feedback was obtained, i.e. customer discovery. Finally, the market-ready device needs to be verified.

The purpose of this manuscript is to share the development process of an orthopedic device to address the subjectivity of joint mobilization techniques. Part of the development of any device involves bench validation and reliability. This is an important first step prior to embarking on clinical research. The following process sought to address validity and reliability.

Methods

The Zeiss Smartzoom 5 Microscope (Carl Zeiss Microscopy, GmbH, Germany) was used as the gold standard to which measures from the Mobil-Aider™ were compared. The Zeiss magnification ranges from 10x to 1011x with coaxial illumination and is self-calibrating. Two metal measurement devices were aligned in parallel, secured to the Mobil-Aider™, and positioned on the Zeiss stage (figure 3). One side of the Mobil-Aider™ device was stabilized and the other side was translated to a random distance (this process was similar to that of a joint mobilization). The measure of the translation was displayed on the Mobil-Aider™ LED screen (in mm) and recorded on the data sheet. With the Mobil-Aider™ in focus on the Zeiss stage, the measure was read off the screen and recorded on a separate data sheet. The Mobil-Aider™ was reset and the process was repeated for a total of 60 times across six different serialized Mobil-Aider™ devices. Thus, a total of two sets of 360 measures were recorded. At the conclusion of all measurements, the two data sheets were matched for Mobil-Aider™ and Zeiss measures. This maintained blinding of all measures. All measurements were made on the base device without any attachments donned. This was because the main device housing is where the linear translation occurs. For this bench research, the addition of an attachment would not have changed any of the measures. However, when collecting clinical research, the contour of the attachment could be a factor and will need to be considered at that time.

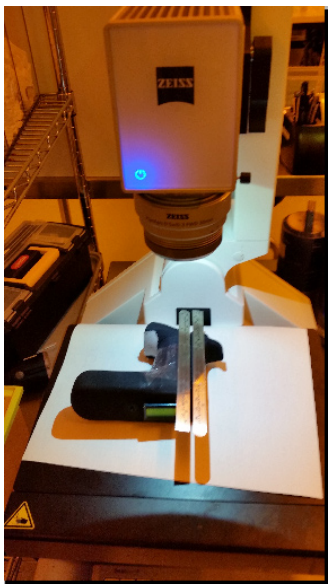

Figure 3: Zeiss Microscope Testing Set-up.

Pearson Correlation was performed to determine how strongly the measures of the two devices resemble each other. A Cronbach's alpha reliability analysis was performed to measure internal consistency (a measure of how well a test addresses different constructs and delivers reliable scores). Independent one-sample t-tests were performed to determine if the two sets of data were significantly different from each other. A Bland Altman Plot was also generated and a linear regression was calculated to check for proportional bias. Finally, a power calculation was performed to determine the confidence in the data.

Results

The data analysis was performed with SPSS Statistics 23 software (IBM, Chicago). Pearson correlation coefficients were calculated because it is deemed the best method of measuring the association between variables based on the method of covariance [25]. The Pearson correlation is a linear index. The correlations

between the device and the Zeiss (across the 6 devices) ranged from 0.986 to 0.997 and demonstrate a strong relationship between the two measures but they do not confirm reliability or validity. Cronbach's alpha is a measure of reliability. The analysis was performed on each device (n=6), as well as the overall measures of all devices. This was done because the alpha coefficient can be increased by simply increasing the number of items on the analysis. Cronbach's alpha range was from 0.992 to 0.997. Independent one-sample t-tests were performed on the differences between the Mobil-Aider™ and the Zeiss values. This was performed to confirm the measures were the same, i.e. validity.

The independent one-sample t-test for all devices was not found to be significant at the p = 0.05 level (p = 0.42). This indicates the measures were not significantly different. In addition, the standard error of the mean was calculated because it is a measure of the dispersion of sample means around the population mean. A low value is a positive reflection of the accuracy of the data. A graph of the values is displayed in figure 4. The Bland Altman plot (figure 5) displays the mean difference and the 95% limits of agreement. No propositional bias was identified. Finally, with 360 pairs of measures, the power of this study was calculated to be 100%.

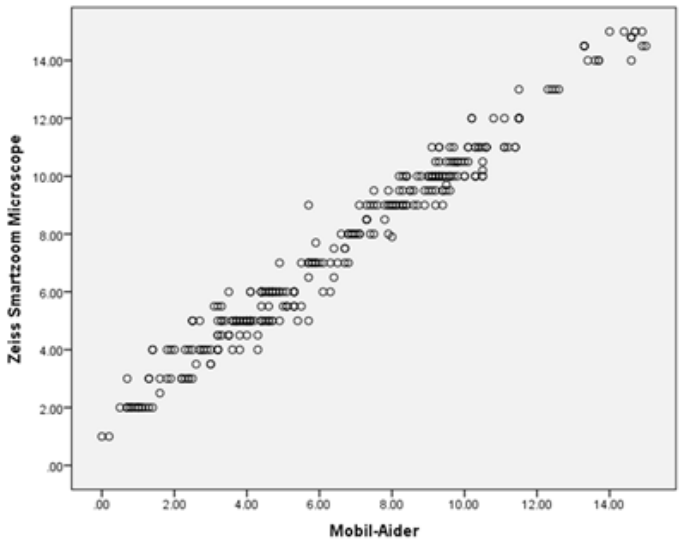

Figure 4: Scatterplot of the Pearson Correlation Coefficient.

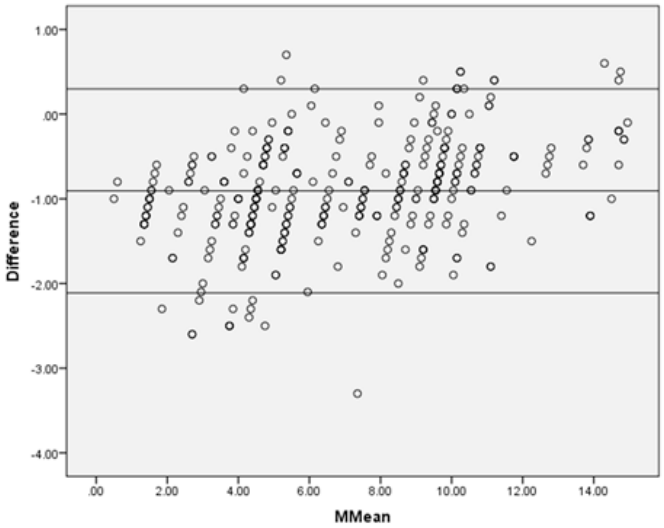

Figure 5: Bland Altman Plot with 95% Upper & Lower Confidence Limits.

Discussion

The results of this study demonstrate both the reliability and concurrent validity of the Mobil-Aider™ in a laboratory setting. This is the first step in determining proof of concept and assessing the clinical viability of any device. Clinical data is the next important step. In theory, if a clinician can obtain quantitative feedback while performing joint mobilizations, consistency of a given grade can be maintained. Students and novice clinicians struggle with the appreciation of various endfeels. If an expert clinician/professor could use a device to demonstrate to a student the magnitude of the linear translation at which a given endfeel occurs, the student can use the device to replicate that translation and appreciate the end feel. For example, a professor, lab instructor, or clinical instructor could identify R2 of a posterior glenohumeral glide as occurring at 8 mm. The student could then perform the same technique to gain a qualitative appreciation of what R2 feels like when achieving 8 mm of translation. In addition, the magnitude of the linear translation can be documented to monitor objective changes over time.

On the other hand, the quantitative feedback can assist the user in identifying faulty technique. If the user does not align the device axis with the joint axis, an LED display will indicate a lack

of movement. The user can then re-assess the joint line and adjust the position of the device to perform an efficacious assessment/intervention. Likewise, since joint mobilizations are a linear translation of two joint surfaces parallel to the joint line, if the user attempts to perform an angular movement, the mechanism of the device will not allow it to translate. Again, this feedback can help a user perform the techniques correctly. This type of feedback is an example of the desired process of acquiring motor skills: learning, error detection, error correction, and training [16].

Currently, there are no other devices capable of quantifying the linear translation of joint surfaces, i.e. arthrokinematic motion. All measurement tools have focused on osteo kinematics, i.e. goniometers. The availability of an arthrokinematic measurement tool to provide objective feedback could be valuable in training evolving professionals, providing consistent interventions, and serve as a research tool to populate the literature regarding efficacious manual techniques. The rendering of proper care may result in quicker recovery, reduced out-of-pocket costs (co-pays), and swifter return to the prior level of function.

Limitations

This manuscript is bench research designed to provide the first step in product validation. The author acknowledges the need to embark on clinical research to demonstrate the ability of the device to perform well on normal and then individuals with pathology.

Conclusions

The data collected in this study are the first step in establishing reliability and concurrent validity of a new device. As a result of the current data, the Mobil-Aider™ device has passed the first test in contributing to quantifying joint mobilization techniques. The next step is clinical testing on both healthy and injured joints.

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