The Mobil-Aider™: Quantifying Joint Mobilizations

Millions of musculoskeletal injuries occur each year, which results in pain, swelling, and limitations in joint movement. Abnormal joint mobility is a component of movement dysfunction (Yerys et al, 2002). Joint mobilization techniques aim to restore the accessory (arthrokinematic) movements between joint surfaces (deSouza et al, 2008; Wise, 2015). Joint mobilizations have been reported to influence a variety of joint structures (Makosky et al, 2007; Yerys et al, 2002). Neurophysiologic alteration in the cutaneous receptors, muscle spindles, and mechanoreceptor threshold has been reported to be an explanation for decreased pain, increased mobility, and increased strength after joint mobilization (Hanrahan et al. 2005; Makosky et al, 2007; Yerys et al, 2002). 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 (Torzilla et al, 1983).

Maitland (1991; 2005) 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 (Maitland, 1991; Maitland, 2005; Wise, 2015). Whereas, grade III and IV mobilizations can be used to address tissue extensibility (Maitland, 1991; Maitland, 2005; Makosky et al, 2007; Wise, 2015). 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 (Gorgos et al, 2014; Tragord et al, 2013). 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 (deSouza et al, 2008; Witt & Talbott, 2016). In addition, displacement is influenced by the rate of force application (Lee & Evans, 1992). 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 (Gorgos et al, 2014).

Major organizations such as the American Heart Association (AHA) have 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. Technology could help address this problem by assessing performance and providing feedback.” Studies have also shown that feedback devices help students achieve mastery of critical resuscitation skills and shorten the time to demonstration of competence. Performing consistent joint mobilizations begins with the way the task is learned in the classroom. Mastering a psychomotor skill requires purposeful practice with feedback (Chang et al, 2007), specifically visual feedback (deSouza et al, 2008). Concurrent feedback given while the learning task is in progress is critical (Chang et al, 2007). Yet, the limited devices available for quantitative feedback of joint mobility are either too cumbersome (Lin et al, 2008; McQuade et al, 2012; Venturini et al, 2007) or measure force (deSouza et al, 2008; Silvernail et al, 2011; Snodgrass, Rivett, Robertson, 2007; Tragord et al, 2013; Tuttle & Jacuinde, 2011). Force is not the operative measure.

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 contours to minimize potential interface errors. Since joint mobilizations can require different amounts of force to reach R1 or R2, 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. This could be done by stabilizing one side/component of a joint while translating the other side/component parallel to the joint surface. The use of a variety of measurement components were explored and connected to 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 the KT1000/2000 device for the assessment of the anterior/posterior cruciate ligaments of the knee. 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 simply 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) can be used 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

This novel device, known as the Mobil-Aider,™ has been funded, in part, by a National Science Foundation Phase I Grant. Throughout the development process, numerous changes were made. Once a minimal viable prototype was created, bench testing was performed and clinical feedback
was obtained. Finally, the market-ready device needs to be verified. The purpose of this study was to assess validity and reliability of the Mobil-Aider™.

**METHODS:**

The gold standard used to assess the Mobil-Aider™ was the Zeiss Smartzoom 5 Microscope (Carl Zeiss Microscopy, GmbH, Germany). The Zeiss is designed for metallographic analysis, inspection of aerospace, automotive, and electronic components, and device failure analysis. Magnification ranges from 10x to 1011x with coaxial illumination. All data was collected in the University of Pennsylvania clean room. The Zeiss is self-calibrating. The metal measurement devices were positioned in parallel, secured to the Mobil-Aider™ and positioned on the Zeiss stage (figure 3). The Mobil-Aider™ device was translated to a random distance. The translation was revealed 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. A total of 360 measures were performed. At the conclusion of all measurements, the 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. The addition of an attachment would not have changed any of the measures.
Intraclass correlation coefficient (ICC) and Pearson Correlations were 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 propositional 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) and began with an ICC to measure the association of the measures as pooled means and standard deviations. Pearson correlation coefficients were calculated because it is deemed the best method of measuring the association between variables based on the method of covariance (Cicchetti, 1994). The Pearson correlation is a linear index. The correlations 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, 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 was from 0.992 to 0.997. Independent one-sample t-tests were performed on the differences between the Mobil-AiderTM 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 measures, the power of this study was calculated to be 100%.

**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 assessing the clinical viability of any device. 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 endfeel. 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. The rendering of proper care can result in quicker recovery, reduced out-of-pocket costs (co-pays), and swifter return to the prior level of function.

The Mobil-Aider™ has the potential to be a transformative device for joint mobilization. The device is light-weight (<370 g; <13 oz), versatile, and cost-effective ($1,499). With seven attachments, an appropriate contour is selected for the joint being mobilized. The attachments are donned and the axis of the device is aligned with the axis of a given joint. The proximal component is stabilized and the distal component is linearly translated. LED feedback is provided. The device design permits the use of standardized joint mobilization techniques so there is a minimal learning curve. Consistency will ensure the desired mobilization grade is administered and will enhance the patient outcome with regard to pain reduction and improved joint mobility.

To this end, the Mobil-Aider™ also has a “mode” switch allowing the user to select “Mode A” to display the maximal joint translation or “Mode B” to display real-time measures. Thus, the user could engage the “A” mode to assess the R2 and then determine the appropriate grade of mobilization to be administered. The mode switch can then be changed to “B” to provide real-time measures during the intervention. For example, if a given joint is determined to reach R2 at
8 mm in “mode A,” the clinician can use “mode B” to obtain real-time feedback when delivering a consistent mobilization technique, i.e. 7-8 mm of translation for a grade IV mobilization.

In addition, 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 roller-ball mechanism of the device will not allow it to translate. Again, this feedback can help a user perform the techniques correctly.

At this time, the Mobil-Aider™ attachments are only designed for the extremities. Attachments for spine mobilizations are not available. Contours of surfaces to achieve stabilization of the adjacent spine structure(s) have not been achieved. As this is explored, additional attachments may be developed.

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 osteokinematics, 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.
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 is a promising orthopedic tool for use in measuring the linear translation associated with joint mobilizations. The next step is additional clinical testing on both healthy and injured joints. IRB approval has been obtained to progress to the collection of clinical data when grant funding is secured.

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DECLARATION OF INTEREST

The author is the PI of the Phase I NSF Grant and the inventor of the Mobil-Aider device.

REFERENCES


