Abstract:

Objectives
Joint mobilizations are often quantified using a 4 point grading system based on the therapist's detection of resistance. It is suggested that the initial resistance to joint mobilizations is imperceptible to therapists, but that at some point through range becomes perceptible, a point termed R1. Grades of mobilization traditionally hinge around this concept and are performed either before or after R1. Physiotherapists, however, show poor reliability in applying grades of mobilization. The definition of R1 is ambiguous and dependent on the skills of individual therapists. The aim of this study is to test a revised grading system where R1 is considered at the beginning of range, and the entire range, as perceived by the therapist maximum force application, is divided into 3, creating 3 grades of mobilization.

Method
Thirty two post-registration physiotherapists and 19 pre-registration students assessed end of range (point R2) and then applied 3 grades of AP mobilizations, over the talus, in an asymptomatic models ankle. Vertical forces were recorded through a force platform. Intra-class Correlation Coefficients, Standard Error of Measurement and Minimal Detectable Change were calculated to explore intra-rater reliability on intra-day and inter-day testing. T-tests determined group differences.

Results
Intra-rater reliability was excellent for intra-day testing (ICC 0.96-0.97), and inter-day testing (ICC 0.85-0.93). No statistical difference was found between pre- and post-registration groups.

Discussion
Standardizing the definition of grades of mobilization, by moving R1 to the beginning of
range and separating grades into thirds, results in excellent intra-rater reliability on intra-day and inter-day tests.

Funding Information:
The intra-rater reliability of a revised 3 point grading system for accessory joint mobilizations, tested on the ankle

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Introduction

Accessory joint mobilizations, widely used by physiotherapists, involve the application of passive rhythmical oscillatory forces to the soft tissues overlying the joint. This technique is often quantified using a subjective grading system. Margarey and Maitland advocated a 4 point grading system based on the therapists’ assessment of resistance to movement. They suggested that although resistance would be encountered the moment that joint movement begun, the initial resistance would be so minor that it would be imperceptible to the therapist. The point at which resistance became perceptible was termed R1, and became the point around which grades of movement were defined. Margarey and Maitland suggested that grades I (small amplitude) and II (large amplitude) movements be applied in resistance free range, before R1. Grades III (large amplitude) and IV (small amplitude) were applied into resistance. Margarey highlighted that the amount of resistance into which the movement be performed might vary, and could be depicted using one or several + or – symbols. For example a grade IV- movement would be performed into a small amount of resistance, whereas a grade IV++ movement would be into a large amount of resistance and might be considered to reach the limit of normal joint range. The grading system was defined according to the onset of resistance (R1) and increase in resistance to end range (R2) as well as the amplitude of movement.

Maitland and Magarey developed a movement diagram to aid communication between therapists and to be used as a teaching tool. It
depicts the behavior of resistance, spasm and pain through the available range of movement and can be used to document a grade of movement used in treatment. The therapist identified on the x-axis the point in range where resistance was first felt (R1). Where resistance limited movement and the therapist was not prepared to apply any more force (R2) was depicted as a thick black line at the end of available range. The quality of the resistance felt during the range was identified by a line drawn between R1 and R2. Lee and Evans suggested that the resistance curve documented on a movement diagram could be considered analogous with a force displacement curve (Figure 1) where R1 was suggested to occur at the transition point between toe and linear region of resistance. Once the behavior of pain or spasm was added to the movement diagram, it could then be used to guide the application of a treatment grade of movement.

Figure 1 about here

Petty, Maher, Latimer and Lee sought to more accurately define R1 by examining 30 force displacement graphs from spinal and peripheral joints. While there was in most graphs a distinct toe region, they failed to find a clear point of inflexion where the linear region began. A lack of demarcation between toe and linear region challenged the use of R1 by therapists when examining joint movement. Petty et al thus proposed R1 would be more accurately considered to occur at the start of movement, A, on the movement diagram.
If the concept of R1 occurring some point through range is questioned, the grading system that hinges around the concept of R1 must also be questioned\textsuperscript{1,2}. Unsurprisingly, research that has explored therapist's application of grades of movement defined by R1 has shown poor reliability. The majority of research has focused on inter-rater reliability with ICC values as low as 0.03-0.05\textsuperscript{8,12,13} suggesting poor reliability. However, variable forces between therapists during grades of mobilizations is expected and warranted as both patient and therapist factors have been shown to influence forces used\textsuperscript{9,14,15}. Patient factors such as age, disability, area and bothersomness of symptoms\textsuperscript{14}, weight, spinal stiffness, range of movement\textsuperscript{15} and therapist factors such as experience, qualification, and frequency of use of mobilizations have all been shown to influence forces used\textsuperscript{14}. Variable forces between therapists might therefore represent best clinical practice, as the therapist is adapting their handling to patients own individual requirements. Additionally we would argue that inter-rater reliability is less clinically relevant than intra-rater reliability as patients are often assessed and treated by only one therapist during their course of treatment.

The research on intra-rater reliability using grades of movement defined by R1, has also however shown poor reliability. Previous work has focused on spinal rather than peripheral joint mobilizations, and therefore is not directly comparable with this research, but can be used to inform common themes identified in therapist reliability. Harms and Bader\textsuperscript{8} explored the intra-rater reliability of applying grades I-IV mobilizations, defined by the detection of resistance, on the L3 vertebra. Thirty experienced therapists were recruited
and applied intra-day and inter-day force applications. The results, when calculated to represent the 95% confidence interval of the population, showed highly variable forces used within therapists repeated measures. Most variability was found for grade I and II mobilizations, which on intra-day testing varied by 63% and 44% respectively. On inter-day testing grades I and II varied by 114% and 94%.

Snodgrass, Rivett, Robertson and Stojanovski\(^9\) found more favorable results for intra-rater reliability. One hundred and sixteen therapists applied 4 grades of mobilization to the C2 and C7 spinal levels, on one of 35 asymptomatic models. The results showed good intra-rater reliability on intra-day testing, with ICC values for vertical forces of 0.93 (0.92-0.94). However there was no standardized definition of grades of mobilization given, rather the participants chose their own definitions, based either on the resistance felt,\(^3\) or the range in movement.\(^10\) When asked what grading system they had used, participants provided a wide range of descriptions, with up to 22 different variables\(^9\) often not related to the detection of R1, but rather related to the available range. The authors found that participants who used range to define their grades of mobilization, rather than resistance, tended to use higher average forces for grade II mobilizations and it is argued that eliminating the ambiguities of detecting the onset of resistance, improved the intra-rater reliability.

Snodgrass et al\(^9\) also examined the impact of therapist characteristics on the forces used during mobilizations and found that therapists with higher academic qualifications tended to use lower forces, but the level of therapist
experience and frequency of use of PA mobilizations had no significant effect
on forces used. They did not explore the impact of therapist experience and
qualifications on the intra-rater reliability however, and there is currently no
research available in this area.

In light of the challenges highlighted in the grading system defined by R1,
Petty\textsuperscript{16} proposed a revised system, where the onset of resistance, R1, was
considered to start at the beginning of range. The therapist perception of end
range, or the maximum force they were prepared to apply determined R2, and
this was expected to vary between therapists. Three grades of movement
were then defined, occurring within the first, middle or last third of resistance,
relative to the therapist's individual assessment of R2. If the resistance were
assumed to be linear, then the three grades would be in the first, middle and
last third of range. The amplitude of oscillation was disentangled from the
definition of grade, and noted separately as a small or large oscillation. So, for
example the treatment dose may be described as a \textit{small amplitude
movement in the middle third of resistance}. This revised and cruder grading
system, which removes the ambiguities of assessing R1, may enhance intra-
therapist reliability, considered in this paper to more clinically relevant than
inter-therapist reliability.

The aim of this study was to test the intra rater reliability of applying forces
within the first, middle and last third of resistance relative to R2. Improving
the accuracy and reliability of grades of movement may help therapists to
determine treatment dose more accurately, and progress and regress
treatments more reliably in clinical practice. As very few studies have focused on the reliability of peripheral joint mobilizations, this study explored AP mobilization on the talus which have been shown to improve joint stiffness and dorsiflexion ROM following ankle sprain.\textsuperscript{17,18}

The aim was also to compare therapists with varying levels of experience as there is currently no research on the impact of experience and qualifications on the intra-rater reliability of performing grades of mobilization.

**Methods**

**Participants**

Participants were recruited via email and then grouped according to their experience and qualifications. Group 1 consisted of 28 chartered physiotherapists (with a minimum of 5 years experience), all of who were attending a postgraduate MSc module in neuromusculoskeletal physiotherapy. In addition, there were 4 lecturers with MSc qualification in Musculoskeletal Physiotherapy and members of the Musculoskeletal Association of Chartered Physiotherapists (MACP). Group 2 consisted of 19 pre-registration physiotherapy students. All participants had experience in the use of applying grades of joint mobilizations and were excluded if they had any recent trauma to the upper limb, neck or thoracic spine, or any pain or impairment that limited or prevented their usual performance of joint mobilization techniques.

The demographic data for therapists is illustrated in Table 1.
Three models were recruited for the study, with an average BMI of 23.98 (range 22.62-25.71) and over 18 years of age.

Apparatus

Force plates (AMTI OR6-7 Advanced Mechanical Technology Inc., Watertown, MA, USA) were used to measure forces applied to the model. The model lay on a lightly padded plinth, which was bolted onto the force platform, so that forces could be indirectly measured as they were transferred through the plinth. Since horizontal forces have been shown to only play a small part in joint accessory mobilizations, only vertical forces were calculated. A lean bar ensured that all the participants force was transferred to force plate. The models ankles were strapped to a wooden platform to maintain plantar grade.

Procedure

For each assessment, the model lay on the same wooden plinth and the same researcher marked the talus with the foot resting in a neutral position. This process was repeated for each model during each data collection period. Only 5 of the participants were familiar with the revised grading system and used it regularly in clinical practice, therefore all participants were provided
with a diagram explaining the revised concept of R1, R2 and the thirds of resistance. To aid understanding this process was repeated verbally prior to initial testing. Participants were allowed to use any amplitude they chose, as this was not being recorded. They were then offered the opportunity to ask questions or seek clarification concerning any aspect of the task.

Participants were allowed time to familiarize themselves with the joint accessory motion at the ankle, by applying repeated oscillatory mobilizations to fully explore the range and judge where point R2 occurred. A minimum of 3 oscillations to end range has been shown to adequately precondition the tissues, therefore participants were asked to assess R2 at least 3 times prior to testing.

Once R2 had been fully explored by the participants they began oscillating within the first third of resistance and data collection started. After approximately 6s participants were prompted to oscillate into the middle third of resistance, without removing their hands, and then into the last third of resistance. Participants were finally asked to find R2 and the force applied at this point was recorded. Participants were free to use amplitude and speed of their choice for each mobilization, as this was not being analyzed. After a break of 5 minutes this process was repeated again in the same order. The participants then returned approximately 1 week later to repeat the same process, but this time only once.
The School of Health Professions, School of Research Ethics and Governance Panel approved the study.

Data analysis

The mobilization forces used were converted into graph format (Figure 2). R2 force was identified as the final maximum peak force.

Figure 2 about here

The graphs were analyzed to determine the mean peak force during the first, middle and last third of resistance. The initial peak force of each third was discounted, as Latimer et al. suggested this initial force reading is more variable in nature than the remaining forces. The mean peak force for the first, middle and last third of resistance was calculated from the 2nd 3rd and 4th oscillation.

Data representing the mean peak forces for each third and R2 was tested for normality using Shapiro-Wilks analysis and in the event of abnormally distributed data, it was transformed using Log10. Transformed data was then reanalyzed to ensure normality. An Independent two-tailed T-Test was used to determine whether differences between the pre-registration and post-registration groups existed.
Reliability was established by calculating ICC and SEM values each third and R². These were calculated on untransformed data, as the tests are based on ANOVAs which have been shown to be robust to deviations in data. Groups were analyzed together where no group differences were found, and separately where group differences were evident. The minimal detectable change was calculated using the SEM to represent the 95% confidence level.

Results

There was no statistically significant difference between pre and post registration groups (p<.05), except on intra-day tests in the first third of resistance, where the post-registration group applied lower mean forces on initial testing (p=0.03) and on repeat testing (p=0.04). Therefore group results were combined for intra-rater reliability, in all tests except the first third of resistance on intra-day tests.

The mean, standard deviation and range of data for all participants during repeated tests was calculated.

Table 2 about here

The ICC values in the study of between 0.96-0.97 for intra-day testing and 0.85-0.93 for inter-day testing represented excellent reliability (Table 3).

Table 3 about here
Only small variation in force was found on SEM calculations. One SEM represents a confidence level of 68%, so for example, when applying R2 forces, therapist forces would vary by 12.4N on 68% of occasions on intra-day tests and by 25.6N on inter-day tests (Table 3).

The SEM was used to calculate the Minimal Detectable change and this value was calculated as a percentage of the original first force application (Table 4). These results also showed small percent differences in therapists force applications on intra-day testing of between 25-34%. The percent differences on inter-day testing were larger between 38-61%.

Table 4 about here

**Discussion**

Excellent results were found for intra-rater reliability on intra-day testing with ICC of 0.96-0.97 which is better than those found by Snodgrass\textsuperscript{9} of 0.84-0.93. The MDC also demonstrated excellent results, particularly on intra-day testing with forces varying by 25-34%. These results are favorable compared to Harms et al\textsuperscript{8} who calculated the 95% limit of agreement, which is similar to the MDC and expressed this as a percentage of the original force application. Harms et al\textsuperscript{8} found forces varied by 63% and 44% for grade I and II mobilizations, and by 24-40% for grade III, IV and end feel mobilizations.
The study by Harms\textsuperscript{8} required participants to apply grade I and II mobilizations before the onset of perceptible resistance (R1). However R1 has been found difficult to accurately identify during examination of force displacement data.\textsuperscript{7} The results in this study suggest that redefining grades of mobilization improves intra-rater reliability on intra-day testing.

Intra-day reliability is relevant in clinical practice, as therapist will often apply several different joint mobilization doses within a physiotherapy session, commonly lasting 30-60 seconds, with a short break between doses.\textsuperscript{3} It seems important that therapists can reliably replicate force between repetitions within a treatment session to ensure consistency and to have the ability to deliberately reduce or increase force to regress or progress the treatment dose. Lack of control of force application could potentially be detrimental to patient care.

Good results were also found for intra-rater reliability on inter-day testing with ICC values of between 0.85-0.93. Although the reliability on inter-day testing is slightly lower than intra-day testing, this is expected as the viscoelasticity of tissues can vary with temperature, time of day and activity levels of the model.\textsuperscript{9} While room temperature remained the same on each day of testing, the temperature of the model was not measured and may have varied on different days. Models were asked to avoid variation in activity levels between days but this could not be strictly controlled. Finally, while every effort was made to repeat measures at the same time of day this was not always the case and length of time since getting up from bed, which would affect the
spine, was not standardized. Snodgrass\(^9\) argued that inter-day testing should not be explored as these factors would make the results too variable, however in clinical practice it is standard to treat patients with multiple treatment sessions on different days\(^3\) where both patient and therapist factors might vary. Inter-day reliability therefore remains an important aspect of the therapist’s treatment, and the good ICC results found in this study suggest that therapists were reliable in their force application, despite differences across days.

The MDC also demonstrated good results on inter-day testing with forces varying by 38-61%. These results are again favorable compared to Harms et al\(^8\) who found much wider variations in force application on inter-day tests of up to 114% and 94% for grade I and II mobilizations respectively, and by 32%-55% for grade III, IV and end feel mobilizations. This suggests that this 3-point grading system resulted in improved inter-day reliability.

Overall there was no significant difference between pre and post registration groups in the reliability of applying the 3-point grading system. No previous research has explored the effect of therapist qualifications and experience on intra-rater reliability when applying grades of mobilization, but this study suggests that therapists of all levels of experience are able to reliably replicate the 3 point grading system.

Limitations
In order to accurately record vertical forces, participants had to apply the
mobilization in a way that differed from their typical practice. They were required to
use a lean bar which kept them at a distance from the model and prevented
them from applying the mobilization in their usual way. The participant’s
handhold was limited to an overhand grip over the anterior surface of the talus
only. Several participants commented on how unnatural this felt. It seems
reasonable to suggest that these alterations to the participant’s normal
procedure in applying an AP to the talus would affect their ability to accurately
and reliably perform the mobilizations. Participants were required to move
from the first third oscillations to the middle third to the last third and then to
R2 without taking their hands off the talus. Participants noted they would
normally remove their hands and re-palpate when changing the grade of
movement, and that the successive application of different grades felt quite
unnatural. In addition, most participants were not familiar with the new grading
system and therefore would have been learning how to apply a new technique
during data collection. These requirements would be expected to lead to a
reduction in reliability.

The therapist used the initial exploration of R2 as the reference point from
which to apply oscillations in the first third and subsequent grades, but this R2
force was not measured; R2 force was instead measured at the end of the
three grades of movement, in order to reduce the complexity of data collection.
It is uncertain whether the measured R2 force accurately reflects the R2 force
used by the therapist to determine the grade of movement and could have led
to inaccurate data. During data analysis, the reliability was captured from the
initial oscillations and not from the full 6 seconds, which might have biased
towards better reliability than measuring over a longer time period.

In order to limit the cumulative effect of repeated joint mobilizations, 3 models
were recruited rather than 1. By using 3 models, the varying weight, ankle
range of motion and age may have also resulted in variable forces between
participants. For example, a model with a stiffer ankle might have resulted in
larger forces being applied to this model compared with others. On inter-day
testing, efforts were made to ensure the experimental conditions remained
similar, as previously described, by using the same model and asking them to
do a similar level of physical activity on both days, however it was not possible
to control for small variations.

The results of this study are limited by the use of asymptomatic models, and
cannot be generalized to a patient population, where pain and abnormal
movement may be present during the PA movement. The results are also
limited to the ankle, and future work focusing on other peripheral and spinal
joints are needed.

**Conclusion**

The redefined grades of mobilizations that assumed R1 started at A in the
movement diagram, was found to have excellent intra-rater reliability on inter-
day and intra-day testing. Therapists of all levels of qualification and
experience were equally able to apply this 3 point grading system with excellent intra-rater reliability.
References


Table 1. Therapist participant demographic data

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<th>Weight (kg)</th>
<th>Years of experience</th>
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<td>172 (9.1)</td>
<td>72.4 (13.7)</td>
<td>6.2 (3.8)</td>
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<td>45-95</td>
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<td><strong>Pre reg therapists(19)</strong></td>
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<td>91 (40)</td>
<td>81 (36)</td>
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(N)= Newton’s
Table 3, ICC with 95% confidence interval and SEM(N)

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<td>21.9</td>
</tr>
<tr>
<td>3rd third</td>
<td>0.97 (.96-.99)</td>
<td>12</td>
<td>0.88 (.80-.93)</td>
<td>24.5</td>
</tr>
<tr>
<td>R2</td>
<td>0.97 (.96-.99)</td>
<td>12.4</td>
<td>0.88 (.79-.93)</td>
<td>25.6</td>
</tr>
</tbody>
</table>

ICC – Intraclass correlation coefficient (95% confidence interval)

SEM = standard error of measurement
Table 4,

Minimal detectable change (MDC) representing 95% confidence level. MDC expressed as a % of the initial force application (day1, test1)

<table>
<thead>
<tr>
<th></th>
<th>MDC95 Intra-day test</th>
<th>Intra-day MDC as a % of initial force</th>
<th>MDC95 inter-day test</th>
<th>Inter-day MDC as a % of initial force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st 3rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre reg</td>
<td>25</td>
<td>25%</td>
<td>38</td>
<td>38%</td>
</tr>
<tr>
<td>Post reg</td>
<td>27</td>
<td>34%</td>
<td>48</td>
<td>61%</td>
</tr>
<tr>
<td>2nd 3rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>29%</td>
<td>61</td>
<td>53%</td>
</tr>
<tr>
<td>3rd 3rd</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>21%</td>
<td>68</td>
<td>43%</td>
</tr>
<tr>
<td>R2</td>
<td>34</td>
<td>20%</td>
<td>71</td>
<td>41%</td>
</tr>
</tbody>
</table>
Figure 1

Relationship of movement diagram (ABCD) to load displacement curve (Reproduced with kind permission from Lee R, Evans J 1994 Towards a better understanding of spinal posteroanterior mobilizations Physiotherapy 80: 68-73)
Figure 2

Example data for ankle joint mobilization

Example of force data collection from one participant demonstrating the oscillations performed during the first, middle and last third of resistance and R2.