Repeatability of Kinematic, Kinetic, and Electromyographic Data in Normal Adult Gait


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Summary: The repeatability of gait variables is an important consideration in the clinical use of results of quantitative gait analysis. Statistical measures were used to evaluate repeatability of kinematic, kinetic, and electromyographic data waveforms and spatiotemporal parameters of 40 normal subjects. Subjects were evaluated three times on each test day and on three different test days while walking at their preferred or natural speed. Intrasubject repeatability was excellent for kinematic data in the sagittal plane both within a test day as well as between test days. For joint angle motion in the frontal and transverse planes, the repeatability was good within a test day and poor between test days. Poor between-day repeatability of joint angle motion in the frontal and transverse planes was noted to be partly due to variabilities in the alignment of markers. Vertical reaction and fore-aft shear forces were more repeatable than the mediolateral shear force. Sagittal plane joint moments were more repeatable than frontal or transverse plane moments. For electromyographic data, repeatability within a day was slightly better than between test days. In general, the results demonstrate that with the subjects walking at their natural or preferred speed, the gait variables are quite repeatable. These observations suggest that it may be reasonable to base significant clinical decisions on the results of a single gait evaluation. Key Words: Gait analysis—Repeatability—Coefficient of multiple correlation—Kinematics—Kinetics—Electromyography.

Quantitative gait analysis using a computer-aided motion analysis, force measurement system and dynamic electromyography is beginning to be recognized as a valuable tool in the assessment of gait disabilities and in the objective evaluation of treatment. However, quantitative gait analysis has not gained widespread clinical acceptance due to a number of reasons noted by Brand and Crowningshield (3). Specifically, one of the main reasons is that the reliability of these complex measurements in terms of repeatability has not been sufficiently established. It is crucial to ask whether or not results from a single gait evaluation is representative of a subject’s overall gait performance and whether the data are consistent enough from day to day for making significant, clinical decisions.

While the literature is replete with normative data on various gait descriptors, there have been no systematic or definitive studies on the repeatability (intrasubject variability) of kinematic and kinetic data, although some work is available on dynamic electromyography (4,7,12–16). Studies on the repeat-
ability of kinematic and kinetic data are fewer. Winter (12) reported on intersubject and intrasubject repeatability of kinematic and kinetic data, utilizing the coefficient of variation (CV). Intrasubject repeatability results were based on two subjects, where one subject was evaluated on different test days and another was evaluated at different times (at 10 min intervals) on the same day. These limited results on sagittal plane motion, moments, and phasic muscle activity demonstrated that intrasubject repeatability was better within the same day of testing compared to results from different test days.

In this paper, we present a comprehensive study of intrasubject repeatability results based on repeated gait analysis on 40 normal, adult subjects. Three-dimensional joint angle motion, foot floor reaction forces, and electromyographic data were recorded on each of the 40 subjects. Moments of force at each joint were computed using a multiple segment model of lower extremity. Repeatability within a test day and between test days were quantified using statistical measures of similarity of waveforms.

MATERIALS AND METHODS

Data Acquisition

Three-dimensional trajectories of body surface markers for computing joint angle motion were acquired using a computer-aided motion analysis system (VICON, Oxford Metrics Ltd., Oxford, England). The system utilized five infrared cameras located around a 6 m walkway and the arrangement was such that when the subject walked in the positive X direction, four of the five cameras were used to record the trajectories of markers placed on one side (for example, the right side) of the subject. The data for the other (left) side were acquired with the subject walking in the negative X direction. This type of unilateral recording arrangement permitted all of the markers to be seen by at least two cameras throughout the gait cycle, thus eliminating the need to interpolate marker trajectories due to missing markers. The camera parameters as well as their positions were also optimized with a view to minimize errors in the computation of marker trajectories (6,8).

Small (2 cm diameter), lightweight (4.4 g), retroreflective markers were applied to the shoulders (acromion process), anterior superior iliac spines (ASIS), and to other key locations on the particular lower extremity in question. These locations included the lateral aspect of the greater trochanter, the knee joint line (posterior to the lateral femoral condyle), the lateral malleolus, and the dorsum of the foot between the second and third metatarsals. A posterior sacral wand (8 cm long) was attached to the pelvis to measure the orientation of the pelvis (pelvic tilt). Two lateral wands (7 cm long) were attached to the thigh, midway between the hip and knee joints, and the shank, midway between the knee and ankle joints, in order to measure rotation angles more accurately. The wands were supported by rigid bars housed in elastic cuffs. The design of the cuffs and the length of the wands were such that the oscillations of the marker at the tip of the wands were insignificant. The hip joint center (HJC) was estimated using regression equations with the leg length as an independent variable (J. Gage and S. Tashman, personal communication). HJC estimates were also compared to estimates using the distance between the ASIS as an independent variable (2), and the difference in the absolute distance between the two techniques was less than 2 cm. The knee center was assumed to lie in a plane defined by the HJC, thigh wand marker, and knee marker, halfway between the femoral condyles. The ankle joint center was assumed to be in a plane defined by the knee joint center, shank wand marker, and ankle marker, one-half the distance between the malleoli. Euler angle definitions and a system of embedded coordinates were used to compute three-dimensional rotations of the pelvis, hip, knee, and ankle.

Foot–floor reaction forces were recorded using two force platforms (Advanced Mechanical Technologies, Inc., Newton, MA, U.S.A.). For each test, the path of the center of pressure and the torque about the center of pressure were computed. Kinematic and kinetic data were acquired at a sampling rate of 50 frames/s. Kinematic and kinetic data along with body segment parameters and linear and angular velocities were used to compute three-dimensional moments at the hip, knee, and ankle joints. Body segment parameters for each subject were computed using the regression equations of Hinrichs (5). The detailed methodology used in computing the three-dimensional joint moments have been described recently by Ramakrishnan et al. (10).

On the same group of subjects, electromyographic data were recorded using surface electrodes (Motion Control, Inc., Salt Lake City, UT, U.S.A.); a detailed description of the instrumentation and methods is given in detail in ref. 7. Foot
contact patterns were recorded using miniature foot switches taped to the heel, first metatarsal, fifth metatarsal, and great toe of each foot. EMG data were bandpass filtered (20–500 Hz) and were sampled along with the footswitch data at 1024 points/s. Electromyographic data were rectified and smoothed with a 32 ms moving window averager (7).

Gait analysis was performed on 40 adult normal subjects (age range of 18–40 years), three times on three different test days at least 1 week apart. The selection of normal subjects was based on the criterion that they had no previous history of any type of musculoskeletal problems. On each test day, the subject was instrumented and was asked to walk back and forth along a timed, 6 m walkway in order to get familiar with the surroundings. The subject was instructed to walk at his/her self-selected or natural speed and data were recorded over three different runs for each side. A single gait cycle of kinematic and kinetic data were recorded for each run. For electromyographic data, three or more gait cycles were recorded over the 6 m walkway.

Data Analysis

For each run, the beginning and end of the gait cycles were identified using the foot contact patterns. Kinematic, kinetic, and electromyographic data were then divided into individual gait cycles using the beginning and end of gait cycles. The gait cycles were normalized to a uniform length of 64 sample points (representing 100% of the gait cycle), each interval representing about 1.6% of the gait cycle. The electromyographic data were also normalized with respect to the maximum amplitude within each gait cycle in order to reduce the variability in phasic muscle activity due to variations in electrode position and electrode excitation voltage and possible fluctuations in the electrode–skin interface characteristics between runs within a day as well as between test days.

Repeatability Measure for Spatiotemporal Parameters

Velocity, cadence, swing to stance ratio, and stride length were calculated using footswitch data. Mean and standard deviation of spatiotemporal parameters were computed for each test day as well as over three test days. For each subject, coefficient of variation (CV), defined as the ratio of the standard deviation to the mean value, was computed as a measure of within-day and between-day repeatability (1). For within-day CV, the mean and standard deviation of gait parameters from three runs were used while between-day CV was calculated from gait parameters from all nine runs. For each parameter, the coefficient of variation was averaged over the number of subjects and the population mean and standard deviation of within-day and between-day CVs were computed.

Repeatability Measures for Kinematic, Kinetic, and Electromyographic Parameters

Kinematic, kinetic, and electromyographic parameters, when expressed as a function of gait cycle, result in graphic waveforms. In describing the similarity or variability of waveforms, simple statistics do not yield satisfactory results and are not descriptive of the variability between waveforms. In this study, a statistical measure, namely the adjusted coefficient of multiple determination (9,11), \( R^2_a \), was used to evaluate the similarity between waveforms. The adjusted coefficient of multiple determination for evaluating the repeatability of waveforms within a test day is given by

\[
R^2_a = 1 - \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{t=1}^{T} (Y_{ijt} - \bar{Y}_{it})^2/M(T(N - 1))}{\sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{t=1}^{T} (Y_{ijt} - \bar{Y}_i)^2/M(NT - 1)}
\]

where \( Y_{ijt} \) is the \( t \)th time point of the \( j \)th run on the \( i \)th test day, \( \bar{Y}_{it} \) is the average at time point \( t \) on the \( i \)th test day, where

\[
\bar{Y}_{it} = \frac{1}{N} \sum_{j=1}^{N} Y_{ijt}
\]

\( \bar{Y}_i \) is the grand mean on the \( i \)th day and is given by

\[
\bar{Y}_i = \frac{1}{NT} \sum_{j=1}^{N} \sum_{t=1}^{T} Y_{ijt}
\]

The coefficient of multiple determination for evaluating the similarity or repeatability of waveforms between test days is given by

\[ J Orthop Res, Vol. 7, No. 6, 1989 \]
$R_a^2 = 1 - \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{t=1}^{T} (Y_{ijt} - \bar{Y}_t)^2 / (MN - 1)}{\sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{t=1}^{T} (Y_{ijt} - \bar{Y})^2 / (MNT - 1)}$ (4)

where $\bar{Y}_t$ is the average at time point $t$ over $NM$ gait cycles,

$\bar{Y}_t = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} Y_{ijt}$ (5)

and $\bar{Y}$ is the grand mean over time and is given by

$\bar{Y} = \frac{1}{MNT} \sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{t=1}^{T} Y_{ijt}$ (6)

In expression (1), the numerator of the ratio on the right-hand side (RHS) represents the variance about the mean at time point $t$ for a particular day, whereas in expression (4), it represents the variance about the mean at time point $t$ over all test days. Similarly, the denominator of the ratio in Eq. (1) represents the total variability about the grand mean for the particular day while the denominator of the ratio in Eq. (4) represents the total variability about the grand mean of all test days. When the waveforms are similar, the numerators of the ratio in the RHS in Eqs. (1) and (4) tend to 0 and $R_a^2$ tends to 1. If the waveforms are dissimilar, both the numerator and denominator approximately represent the estimate of the same variance and the ratio tends to $1$ and $R_a^2$ tends to zero. Thus, expression (1) yields a measure of repeatability of waveforms within a test day and is a combined measure over three individual test days, while the expression in Eq. (4) yields a measure of between-day repeatability. The positive square root of the adjusted coefficient of multiple determination is called the adjusted coefficient of multiple correlation (CMC) and will be used to describe the repeatability of kinematic, kinetic, and electromyographic data. For the electromyographic data, the coefficient of variation (CV) described by Winter (12,13) was also computed.

RESULTS

The mean and standard deviation of spatiotemporal parameters for a representative subject over the 3 days of testing are shown in Fig. 1. The results for other subjects in the group were similar and depict the fact that the subjects walked repeatably on different days of testing. The mean and standard deviation of within-day and between-day repeatability of spatiotemporal parameters reflected by the corresponding coefficients of variation (CV) are shown in Table I. In general, the coefficients of variation for cadence and stride length were lower than the velocity or swing to stance ratio. Repeatability of spatiotemporal parameters within a test day were higher than the results between test days.

The mean and standard deviation of joint angle motion in the sagittal, frontal, and transverse planes for a representative subject over three different days of testing (nine cycles) are shown in Fig. 2A, B, and C, respectively. The corresponding values of the adjusted coefficient of multiple correlation (CMC) depicting the similarity between waveforms are also indicated. The mean and standard deviation of CMC representing within-day and between-day repeatabilities for all of the subjects in this group are shown in Table 2. In the sagittal plane, the repeatability of joint angle motion at the hip, knee, and ankle were excellent both within a test day as well as between test days. Pelvic tilt pattern displayed the lowest repeatability. The CMCs for the joint angle motion in the frontal and transverse planes were lower than those for sagittal plane motion. The repeatability for all of the angles was better within a test day than when compared to between test days.

Despite extreme care taken in the reapplication of markers on different test days, a certain amount of uncertainty exists in repositioning the sacral, thigh, and shank wand markers. This results in the introduction of a constant offset to the pelvic tilt, hip flexion-extension and transverse plane joint angles. In other words, these joint angle patterns are shifted up or down by a constant amount while the shape remains unchanged. In order to eliminate the effect of the offset on the repeatability, the mean value of waveforms for the particular day was removed from each joint angle pattern and the CMCs were recomputed for a true estimate of between-day repeatability. For between-day repeatability, the CMCs calculated before and after removal of the mean for the
particular day are shown on Table 2. The between-day repeatabilities (with the exception of knee varus/valgus) for pelvic tilt as well as for the joint angles in the frontal and transverse planes improved dramatically but were still lower than their corresponding within-day repeatabilities.

The mean and standard deviation of CMCs for the foot-floor reaction forces as well as joint moments are shown in Table 3. The variability of vertical reaction force and fore-aft shear was lower than that for mediolateral shear or torque about the center of pressure. In general, the patterns of foot-floor reaction forces were extremely repeatable within a single day as well as between days of testing. The joint moment patterns in the sagittal, frontal, and transverse planes for a representative subject over three test days are shown in Fig. 3A, B, and C, respectively, along with CMC, reflecting within-day and between-day repeatabilities. The repeatability of moments of force at the knee was lower
Pelvic Tilt

CMC (w) = 0.598
CMC (b) = 0.529

Hip Flexion-Extension

CMC (w) = 0.995
CMC (b) = 0.994

Knee Flexion-Extension

CMC (w) = 0.991
CMC (b) = 0.967

Dorsi-Plantarflexion

CMC (w) = 0.975
CMC (b) = 0.968

Pelvic Rotation

CMC (w) = 0.893
CMC (b) = 0.871

Hip Rotation

CMC (w) = 0.882
CMC (b) = 0.845

Knee Rotation

CMC (w) = 0.941
CMC (b) = 0.861

Ankle Rotation

CMC (w) = 0.933
CMC (b) = 0.881

than those at the hip or ankle. The repeatability of moments in the sagittal plane was better than those in the transverse or frontal planes. Repeatability between days was slightly lower than repeatability within a day.

The mean patterns of electromyographic data (nine cycles from 3 days) from a representative subject are shown in Fig. 4 along with CMC and CV, depicting both within-day and between-day repeatabilities. The mean and standard deviation of coeff-

### TABLE 2. Mean and standard deviation of the coefficient of multiple correlation (CMC) for the group of normal subjects: joint angle motion

<table>
<thead>
<tr>
<th>Joint angle</th>
<th>CMC within a day</th>
<th>CMC between days (with mean of each day removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>Pelvic tilt</td>
<td>0.669 ± 0.134</td>
<td>0.643 ± 0.180</td>
</tr>
<tr>
<td>Hip flexion/extension</td>
<td>0.996 ± 0.003</td>
<td>0.995 ± 0.005</td>
</tr>
<tr>
<td>Knee flexion/extension</td>
<td>0.994 ± 0.005</td>
<td>0.994 ± 0.003</td>
</tr>
<tr>
<td>Ankle dorsiflexion/plantar</td>
<td>0.975 ± 0.018</td>
<td>0.978 ± 0.010</td>
</tr>
<tr>
<td>Pelvic obliquity</td>
<td>0.961 ± 0.030</td>
<td>0.956 ± 0.045</td>
</tr>
<tr>
<td>Hip abduction/adduction</td>
<td>0.964 ± 0.030</td>
<td>0.957 ± 0.088</td>
</tr>
<tr>
<td>Knee varus/valgus</td>
<td>0.942 ± 0.044</td>
<td>0.962 ± 0.029</td>
</tr>
<tr>
<td>Pelvic rotation</td>
<td>0.860 ± 0.090</td>
<td>0.878 ± 0.069</td>
</tr>
<tr>
<td>Hip rotation</td>
<td>0.893 ± 0.064</td>
<td>0.893 ± 0.072</td>
</tr>
<tr>
<td>Knee rotation</td>
<td>0.911 ± 0.090</td>
<td>0.918 ± 0.053</td>
</tr>
<tr>
<td>Foot rotation</td>
<td>0.853 ± 0.080</td>
<td>0.885 ± 0.053</td>
</tr>
</tbody>
</table>
3A  
**Hip Flexion/Extension Moment**

![Graph showing Hip Flexion/Extension Moment with %Nm/(BW·LL) on the y-axis and % Gait Cycle on the x-axis.]

**Knee Flexion/Extension Moment**

![Graph showing Knee Flexion/Extension Moment with %Nm/(BW·LL) on the y-axis and % Gait Cycle on the x-axis.]

**Ankle Flexion/Extension Moment**

![Graph showing Ankle Flexion/Extension Moment with %Nm/(BW·LL) on the y-axis and % Gait Cycle on the x-axis.]

3B  
**Hip Ab/Adduction Moment**

![Graph showing Hip Ab/Adduction Moment with %Nm/(BW·LL) on the y-axis and % Gait Cycle on the x-axis.]

**Knee Ab/Adduction Moment**

![Graph showing Knee Ab/Adduction Moment with %Nm/(BW·LL) on the y-axis and % Gait Cycle on the x-axis.]

**Ankle Ab/Adduction Moment**

![Graph showing Ankle Ab/Adduction Moment with %Nm/(BW·LL) on the y-axis and % Gait Cycle on the x-axis.]
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3c Hip Rotational Moment

Knee Rotational Moment

Ankle Rotational Moment

FIG. 3. Mean and standard deviation of normalized joint moment patterns (nine cycles from 3 days) for the representative subject along with within-day (w) and between-day (b) coefficients of multiple correlations in the (A) sagittal plane, (B) frontal plane, and (C) transverse plane.

The group of subjects evaluated in this study walked repeatably within a test day as well as between test days and this was depicted by the very low values of the coefficient of variation of spatiotemporal parameters. The results showed that when the subjects are instructed to walk at their natural or preferred speed, without the aid of visual or aural cues, the subjects tended to keep the cadence and stride length less variable than walking speed. These results are in agreement with our previous results (7).

The intrasubject repeatability of joint angle motion is influenced by the inherent physiological variability as well as those introduced by the measurement system. The latter includes the effects of finite accuracy and resolution of the motion analysis system and the marker system used in the computation of joint angle patterns. In this study, every effort was made to minimize the magnitude of the effects due to the motion measurement system (6). Since it is impossible to uncouple the effects of the finite accuracy and resolution of the motion measurement system, the repeatability results reported in this study include their contribution. To minimize the uncertainties in the reapplication of markers on successive days of testing, a single, well-trained operator performed all of the marker applications. Despite the extreme care taken in the reapplication of markers, it was difficult to align the femoral and tibial wand markers in a repeatable manner. The
misalignment of the wand markers introduced a constant offset to some of the measured joint angle patterns. In particular, the frontal and transverse plane angles were affected more than the sagittal plane angles. Further, it was observed that for the knee varus/valgus motion, the offset was not constant during the swing phase of the gait cycle. In order to eliminate the effect of the marker reapplication errors, the mean value of the joint angle motion in the transverse plane motions. The improvement in the between-day repeatability of joint angle motion in the transverse plane, when the mean from each day was removed, demonstrates that these angles are strongly influenced by the variations in the alignment of wand markers.

Marker reapplication errors were minimal on hip abduction/adduction and were significant on the knee varus/valgus motion. The between-day repeatability of knee varus/valgus did not improve significantly even after the removal of the mean value. This may be attributed to the variable offset introduced by errors in femoral wand alignment, which results in a change in the pattern of joint angle motion.

In general, the lower within-day repeatability for pelvis, hip, knee, and ankle joint motion in the transverse plane indicates that the variabilities in pattern of walking for an individual is reflected mostly in the transverse plane motions. The improvement in the between-day repeatability of joint angle motion in the transverse plane, when the mean from each day was removed, demonstrates that these angles are strongly influenced by the variabilities in the alignment of wand markers.

Foot-floor reaction forces displayed excellent repeatability. Most of the variability is attributable to physiological factors since the contribution from the measurement instrumentation is very small. The repeatability of moment patterns at the hip and knee joints was slightly lower than those at the ankle joint with the exception of hip abduction/adduction moment. This may be due to the fact that during the stance phase, the instantaneous position of the hip and knee joint centers may be more variable than the ankle joint center due to the flexibility afforded by the two joint muscles crossing the hip and knee joints (13). It may also be that the uncertainties in estimating the joint centers at the hip and knee are
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Greater than those at the ankle. The variability in moment patterns during the swing phase is attributable to the variations in the estimation of velocity and acceleration of limb segments from marker position data. The repeatability results of joint moment patterns in the sagittal plane were similar to the results reported by Winter (12,13). Between-day repeatability of joint moments was slightly lower than within-day repeatability in all three planes.

In general, the adjusted coefficient of multiple correlations was lower for the electromyographic data than those for the angles, forces, or moments. The CV results in this study were higher than those reported by Winter and Yack (13). This may be due to the fact that in their study, EMG data were smoothed by a filter having a low-pass cutoff frequency of 2–3 Hz, compared to the smoothing used in this study, which had an effective low-pass cutoff frequency of 12–14 Hz. Hence, the processed EMG data used here are inherently more variable compared to those used by Winter and Yack (13) for computing the CV. In general, for waveforms, repeatability results may be improved by providing an additional level of smoothing (4,7). However, in the case of phasic muscle activity, this might act to obscure significant diagnostic information that may be present in the EMG data. The lower between-day repeatability observed for all of the muscles may be due to the fact that, in spite of accurate reapplication of surface electrodes, it is impossible to insure that the same volume of the muscle is sampled on different days of testing. The repeatability of phasic muscle activity of the adductor group (adductor longus) was lower than other muscles tested in this study. The reason for the lower CMC observed for the adductor group is not clear.

In conclusion, the gait patterns were quite repeatable in this group of normal subjects walking at their natural or preferred speed. For joint angle motion in the sagittal plane, the physiological variability was

FIG. 4. Mean and standard deviation of EMG envelopes (nine cycles from 3 days): within-day (w) and between-day (b) coefficients of multiple correlations and coefficients of variations are also shown.
quite small compared to the transverse or frontal plane. The between-day repeatability of joint angle motion in these two planes was dramatically affected by errors in the reapplication of wand markers and should be taken into account while comparing data from two different test days. The variability in the pattern of forces and moments were minimal. The electromyographic data were also quite repeatable both within and between test days. The results suggest that it may be possible to base significant clinical decisions on a single gait evaluation although it is recognized that patients with gait disabilities may have a lower level of repeatability. It may be necessary to develop a profile of repeatability characteristics for different groups of patients. In interpreting the results of gait analysis, our results also suggest that it is important to consider the effect of the measurement system on the patterns of gait variables.

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REFERENCES

TABLE 4. Mean and standard deviation of the coefficient of multiple correlation and coefficient of variation for electromyographic data

<table>
<thead>
<tr>
<th>Muscle/muscle groups</th>
<th>CMC</th>
<th>% CV (present study)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Within day</td>
<td>Between days</td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>0.851 ± 0.060</td>
<td>0.820 ± 0.084</td>
</tr>
<tr>
<td>Gluteus medius</td>
<td>0.854 ± 0.061</td>
<td>0.838 ± 0.062</td>
</tr>
<tr>
<td>Adductor longus</td>
<td>0.746 ± 0.095</td>
<td>0.661 ± 0.117</td>
</tr>
<tr>
<td>Vastus lateralis</td>
<td>0.883 ± 0.050</td>
<td>0.860 ± 0.051</td>
</tr>
<tr>
<td>Rectus femoris</td>
<td>0.856 ± 0.052</td>
<td>0.815 ± 0.068</td>
</tr>
<tr>
<td>Vastus medialis</td>
<td>0.871 ± 0.060</td>
<td>0.843 ± 0.070</td>
</tr>
<tr>
<td>Lateral hamstring</td>
<td>0.837 ± 0.070</td>
<td>0.80 ± 0.090</td>
</tr>
<tr>
<td>Medial hamstring</td>
<td>0.811 ± 0.101</td>
<td>0.756 ± 0.127</td>
</tr>
<tr>
<td>Anterior tibialis</td>
<td>0.840 ± 0.066</td>
<td>0.832 ± 0.060</td>
</tr>
<tr>
<td>Gastrocnemius (medial)</td>
<td>0.899 ± 0.030</td>
<td>0.875 ± 0.040</td>
</tr>
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