Journal of Biomechanics 183 (2025) 112621

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech

Review

Joint moment–angle/velocity relations in the hip, knee, and ankle: A meta-visualization of datasets

Ziyu Chen [a,b], David W. Franklin [a,b,c,*]

[a] Neuromuscular Diagnostics, Department Health and Sport Sciences, TUM School of Medicine and Health, Technical University of Munich, Munich, Germany
[b] Munich Institute of Robotics and Machine Intelligence (MIRMI), Technical University of Munich, Munich, Germany
[c] Munich Data Science Institute (MDSI), Technical University of Munich, Munich, Germany

ARTICLE INFO

Keywords:
Dynamometer
Force–length
Force–velocity
Isokinetic
Isometric
Joint moment
Muscle strength

ABSTRACT

Joint moment is a prominent kinetic property in biomechanical investigations, whose pattern and magnitude reflect many characteristics of musculoskeletal motion and musculotendon biomechanics. Nonetheless, the relations of joint moment with joint angle and velocity are complicated, and it is often unclear how the kinetic capacity of each joint varies in different configurations. With common techniques in systematic review, we collected a total of 962 passive, isometric and isokinetic joint moment datasets based on human *in vivo* measurements from literature and visualized the major joint moment–angle and moment–velocity relations in the hip, knee, and ankle. The findings contribute to the analysis of musculoskeletal mechanics and providing reference regarding the experimental design for future moment measurement.

Contents

1. Introduction

The moment of force in the joint is a major interest in the study of human movement, as it directly associates kinematics with the biomechanics of the muscle–tendon unit (Anderson and Pandy, 1999; Franklin et al., 2003; Hu et al., 2020; Zajac, 1993). The pattern and magnitude of joint moments, calculated via inverse kinematics, is often used in biomechanical analysis as a substitute for the timing and intensity of muscle activities (Franklin et al., 2003; Milner and Franklin, 2005; Raffalt et al., 2016; Robertson et al., 2008), which cannot be easily obtained during dynamic motions (De Luca, 1997). Similarly,

* Corresponding author at: Neuromuscular Diagnostics, Department Health and Sport Sciences, TUM School of Medicine and Health, Technical University of Munich, Munich, Germany.
E-mail address: david.franklin@tum.de (D.W. Franklin).

https://doi.org/10.1016/j.jbiomech.2025.112621
Accepted 7 March 2025
Available online 15 March 2025

maximal joint moment at different joint angles and rotational velocities is an important indicator of muscle strength, and may correlate with movement performance or dysfunction (Boling et al., 2009; Jones et al., 2009; Murphy et al., 2003; Tsiokanos et al., 2002). Data such as isometric and isokinetic moments provide valuable references for medical diagnosis (Ekdahl and Broman, 1992; O'Neill et al., 2019), rehabilitation (Perhonen et al., 1992; Shaffer et al., 2000), and athletic training (Daneshjoo et al., 2013; Handel et al., 1997), as well as play an essential role in the calibration of musculoskeletal models (Anderson and Pandy, 1999; Delp et al., 1990; Holzbaur et al., 2005), which are a convenient tool for the estimation of muscle force or activation (Delp et al., 2007).

Theoretically, joint moment is not particularly difficult to measure: When the actuated limb enacts against an object, a contact force is in effect, and joint moment can be calculated as the product of this force and the distance between the contact point and the joint rotation center. However, despite the importance of isometric and isokinetic moment data or the simplicity of moment measurement, it is still hard to find constructive datasets depicting the relations of moment–angle/velocity in each joint (Anderson et al., 2007; Silder et al., 2007). There is a fundamental reason behind this reality. Unlike the muscle force–length relation, the joint moment–angle relation cannot usually be simplified to one-dimensional since moment-related angle is not necessarily a scalar. For any monoarticular muscle, there are theoretically three rotational degrees of freedom (DoF) that this muscle actuates. In the hip, for instance, all of its muscles should have some level of contribution to its extension/flexion, abduction/adduction, and external/internal rotation. Reversely, a movement in any one of the DoFs affects the lengths of all relevant muscles, their maximal force outputs, and ultimately the maximal moment outputs in all directions. For example, the maximal hip abduction moment may change not only when the hip abducts, but also when the hip flexes or rotates. Therefore, the relation of hip abduction moment with hip position is theoretically three dimensional, and it is the same for hip moments in the other five directions.

This problem is further complicated in biarticular muscles such as the rectus femoris and hamstrings; that is, position of the knee could potentially affect hip moments, and vice versa (Herzog and ter Keurs, 1988; Savelberg and Meijer, 2003). As a result, to fully understand the moment–angle relation of a joint, data must be obtained from a combination of various joint positions involving all related DoFs, which is a time-consuming task. In practice, researchers tend to focus on the sagittal plane, e.g., by keeping the hip in the neutral position of abduction/adduction and external/internal rotation to study the relation between hip extension (or hip flexion, knee extension, knee flexion) moment and the flexion angle of either the hip or knee. Even still, any of these moment–angle relations is two dimensional, and the number of joint positions for isometric measurement increases quadratically compared to the case that would exist if the relation was only one dimensional.

Furthermore, how fast the joint rotates also has an impact on its moment output, and this impact may vary with joint angle (Anderson et al., 2007; Khalaf et al., 2000; Hussain and Frey-Law, 2016). In other words, this relation of joint moment–velocity should always contain one more dimension than the accordant moment–angle relation. Fortunately, the measurement of an isokinetic moment is no more complicated than that of an isometric moment, because in a single isokinetic test, the joint needs to move over a specific range covering joint angles measured in multiple isometric tests. However, it is very common for researchers to measure the isokinetic moment over some range but take the peak or mean value in representation of the moment at the test angular velocity (Boling et al., 2009; Gajdosik, 2002; Vandervoort et al., 1990). By doing so, the muscle force–velocity relation is assumed to be constant across all muscle lengths, which is not necessarily the case.

As a result, there is still great uncertainty behind the seemingly simple question of how much moment a joint could generate in a specific position and rotational velocity. To reveal such potentially complicated biomechanical relations, more varied measurements are of course required to cover a wider range of joint configurations. Nevertheless, before designing a series of large experiments, it is necessary to find out which parts of the joint space are already well-studied and which parts require further measurements.

Here, we extensively collect existing datasets from literature constituting joint moment–angle and joint moment–angular velocity relations for six DoFs in the lower limb. We approach the issue using common techniques in systematic review and we aim to visualize the data with sufficient details to provide reference values for biomechanical analysis, especially musculoskeletal modeling.

2. Methods

In this study, we focus on *in vivo* moment measurements from six major DoFs in the human lower limb:

1. hip extension/flexion,
2. hip abduction/adduction,
3. hip external/internal rotation,
4. knee extension/flexion,
5. ankle plantarflexion/dorsiflexion,
6. ankle eversion/inversion.

For each DoF, there is a passive moment–angle relation. In addition, each DoF is consisted of two directions, whose movements are characterized by two active moment–angle relations and two active moment–velocity relations. Here, we focus on active moment induced by maximal voluntary contraction, rather than submaximal contraction or stimulation. Thus, we look to investigate a total of six passive relations, 12 maximal voluntary isometric relations, and 12 maximal voluntary isokinetic relations.

For each relation, we used a combination of keywords to initiate batch searches in Google Scholar (conducted in November, 2023) with the software Publish or Perish (Version 8; Harzing, 2010). To guarantee search efficiency, we tested multiple combinations of keywords in search of 18 target studies with desired moment data for ankle plantar-/dorsiflexion (Anderson et al., 2007; Andrade et al., 2016; Bobbert and van Ingen Schenau, 1990; Csapo et al., 2010; Danneskiold-Samsøe et al., 2009; Hahn et al., 2011; Hasson et al., 2011; Holzer et al., 2020; Koh and Herzog, 1995; Mademli et al., 2004; Maganaris et al., 1998; Marsh et al., 1981; Riener and Edrich, 1999; Sale et al., 1982; Silder et al., 2007; Simoneau et al., 2007; van Schaik et al., 1994; Winegard et al., 1997). The keyword set selected for the final batch search is one that led to the most target papers (17 out of 18) while having them appear in top search rankings (on average 35th place in the list of 200 results), and it has the format as in Box I.

For all three sagittal DoFs and hip ab-/adduction, which are considered more dominant in motions, we examined the first 500 search results for the isometric relation and 200 each for the passive and isokinetic relations. For the other two DoFs, only the first 200 results for the isometric relation and 100 each for passive and isokinetic were examined. Other details of data collection are shown in Fig. 1 and can also be found in Appendix B. Note that we also initiated searches oriented towards muscle moment arms for another study, but the search results were examined altogether. This serves as a compensation for the potential overfitting of the keywords, in case some records are missed in the searches intended for moment data.

In data collection, if a study presents its data in graphs rather than in numbers, we use Graph Grabber (Version 2.0.2, Quintessa Ltd.) for manual digitization. The data are categorized by attributes listed in Table 1, where primary, secondary and tertiary DoFs denote the variables (joint angle in the respective DoF or velocity) in moment measurement

Part 1 (DoF)
- hip AND (flex OR extens)
- hip AND (adduct OR abduct)
- hip AND (internal OR external OR inward OR outward) AND rotat
- knee AND (flex OR extens)
- (ankle OR plantarflex OR dorsiflex)
- (ankle OR subtalar) AND (inversion OR eversion)

\+

Part 2: AND (moment OR torque) AND angle AND relation AND subject AND joint AND position AND

isokinetic: angle → velocity

\+

Part 3 (State)
- passive
- max AND (voluntary OR isometric)
- max AND (isokinetic OR concentric OR eccentric)

Box I.

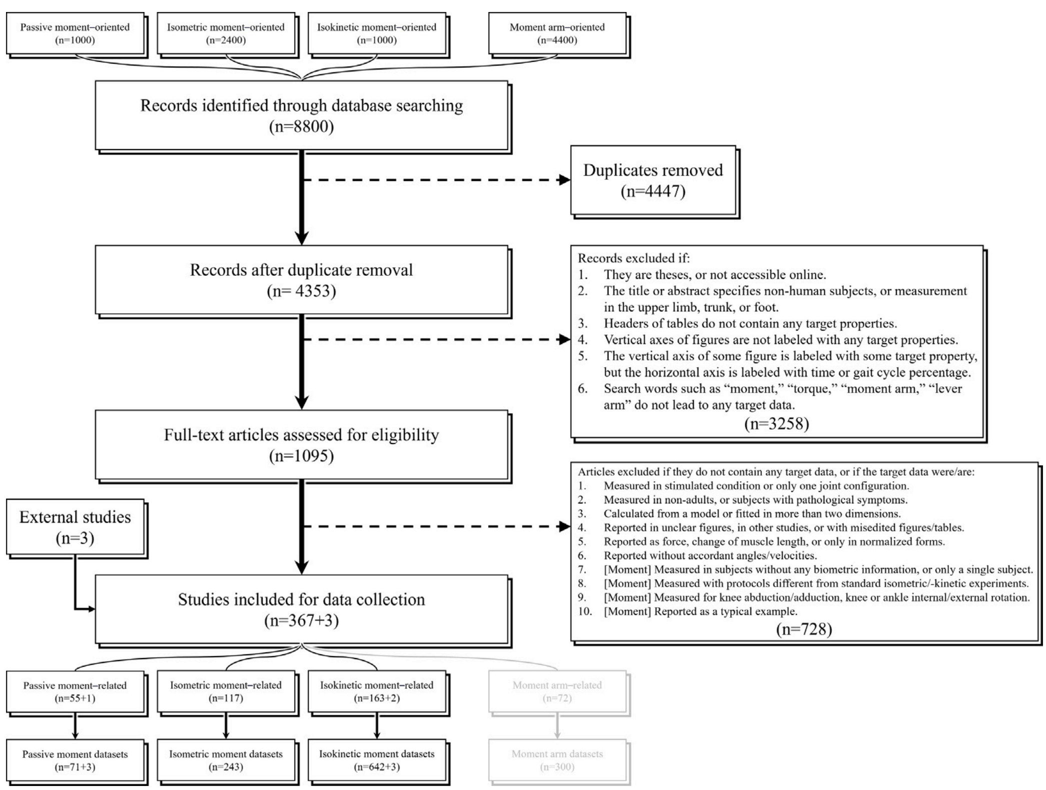

Fig. 1. Workflow of study selection. Moment arm–related datasets are not presented in this study, but records identified by searches intended for moment arm data were examined for moment data.

for the convenience of data storage. These DoFs are ones to which the target moment is sensitive: e.g., hip flexion moment is primarily sensitive to changes in hip flexion angle, so hip flexion/extension is the primary DoF of hip flexion moment. A dataset is defined as a set of measurements with distinction in either its reference, subject information, measured motion, or data type; in a few exceptional cases, datasets are distinguished by the tertiary DoF. In each dataset, there is at least one curve, which is comprised of measurements from at least two joint configurations, and some datasets contain multiple curves, each comprised of multiple measurements. The data for each curve are stored as a 3-column matrix, with the first, second, and third column for the angles in the primary and secondary DoFs, and the moments. The sign rule for angle and moment in each DoF is based on the ISB recommendations (Wu et al., 2002; Derrick et al., 2020) except for knee flexion/extension, which is reversed so that anti-gravity motions share the negative sign. The sign rule for velocity follows after Hill (1938), where concentric is defined as positive. If the angle in the secondary DoF is not specified in a study, we label it as `NaN`.

Due to the massive size of the gathered datasets, we used 3D and 2D plots as a means of visualization to present the data. Importantly, since the data are multidimensional and the measured joint configurations are different across datasets, typical methods of meta-analysis no longer apply, and we did not proceed to combine the results. Also, considering the heterogeneity between studies, we refrain from making conclusive statements for any motion on the representative range and magnitude of joint angle or moment. For biomechanical analysis, readers are

Table 1
Metadata for passive, isometric, and isokinetic datasets.

Dataset	Passive	Isometric	Isokinetic
Reference	Authors (Year)		
Subject info	Sample size, sex, age, height, weight, related profession.		
Motion[a]	① HE/F ② HAb/Ad ③ HExtl/Int ④ KE/F ⑤ AP/D ⑥ AEv/Inv	(1–) Hip E (2–) Hip Ab (3–) Hip Extl (4–) Knee E (5–) Ankle P (6–) Ankle Ev	(1+) Hip Flexion (2+) Hip Adduction (3+) Hip Internal Rotation (4+) Knee Flexion (5+) Ankle Dorsiflexion (6+) Ankle Inversion
Data type	Passive	(I) Total (II) Active	(I) Angle (II) Angle (Peak) (III) Peak (IV) Mean
Primary DoF[a]	① Hip Extension/Flexion ② Hip Ab-/Adduction ③ Hip Ex-/Internal Rotation ④ Knee Extension/Flexion ⑤ Ankle Plantar-/Dorsiflexion ⑥ Ankle Eversion/Inversion		Eccentric/Concentric
Secondary DoF[a]	① Knee Extension/Flexion ② Hip Extension/Flexion ③ Hip Extension/Flexion ④ Hip Extension/Flexion ⑤ Knee Extension/Flexion ⑥ Ankle Plantar-/Dorsiflexion		① Hip E/F ② Hip Ab/Ad ③ Hip Extl/Int ④ Knee E/F ⑤ Ankle P/D ⑥ Ankle Ev/Inv
Tertiary DoF[a]	① – ② Knee Extension/Flexion ③ Knee Extension/Flexion ④ Ankle Plantar-/Dorsiflexion ⑤ – ⑥ Knee Extension/Flexion		① Knee E/F ② Hip E/F ③ Hip E/F ④ Hip E/F ⑤ Knee E/F ⑥ Ankle P/D

[a] Primary, secondary, and tertiary DoFs are ones the target moment is sensitive to and are dependent on the motion, as indicated by the circled number.

encouraged to select datasets with characteristics of subjects and means of measurement conforming to their object of study.

For the potential need of normalization and comparative analysis, we specified the sample size, sex, age, height, and weight of subjects, as well as the information of kinetics-based professions, such as solider, dancer, and athlete. We also marked if isometric data were corrected of the passive moments, and if isokinetic data were obtained as angle-specific, peak, or mean values within the test range of motion. For convenience, we provide a catalog with details of the datasets (see Appendix B). In isokinetic datasets, if the moment data are peak or mean values, the angle in the secondary DoF (the moving DoF) is labeled as `NaN`, but the tested RoM is recorded in our catalog if specified in the original study. Other information, such as gravity correction, EMG-monitored muscle inactivation, and the order of isokinetic measurements (e.g., reciprocal concentric–eccentric), is also recorded in the metadata if specified in the original study.

Table 2
Distribution of datasets for each motion.

Motion	Number of datasets		
	Passive	Isometric	Isokinetic
Hip extension Hip flexion	7 (2)	11 (3) 7	33 29
Hip abduction Hip adduction	1 (1)	10 (2) 6 (1)	26 (1) 24 (1)
Hip external rotation Hip internal rotation	0	10 (5) 9 (4)	23 (2) 19 (2)
Knee extension Knee flexion	11 (3)	53 (7) 23 (1)	161 (46) 123 (29)
Ankle plantarflexion Ankle dorsiflexion	54 (9)	78 (20) 32 (1)	108 (19) 62 (10)
Ankle eversion Ankle inversion	1	2 2	19 18

The bracketed number denotes the number of datasets related to the moment–angle relation in the secondary DoF, while the unbracketed number is for the primary DoF.

3. Results

As shown in Fig. 1, a total of 367 studies were identified from 4353 records searched in the database. Along with three external studies, the identified studies yielded 74 passive datasets, 243 isometric datasets, and 645 isokinetic datasets. Table 2 shows the distribution of datasets for each motion. See Appendix A for the list of collected studies and datasets.

The gathered datasets are visualized in 3D and 2D plots (Figs. 2–11, 13–17). The age and sex of the subject group are indicated by the shape

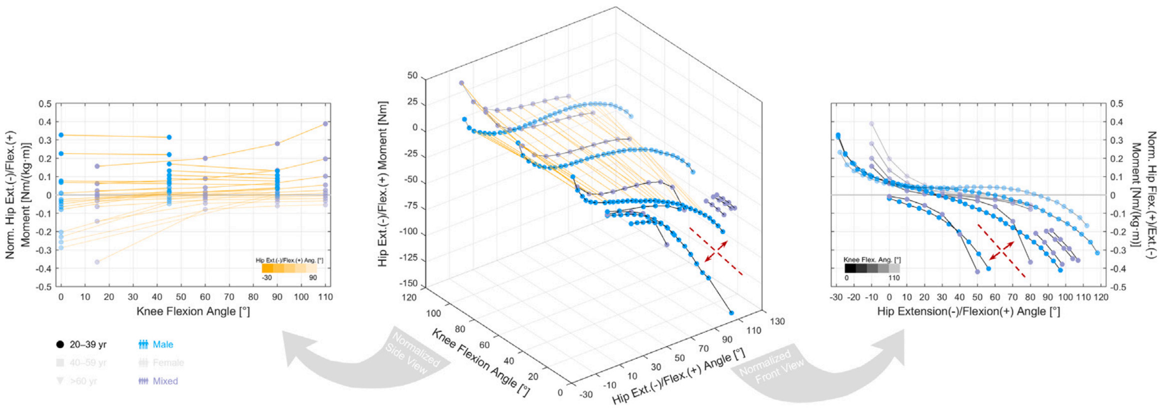

Fig. 2. Relations of passive hip extension/flexion moments. Left: Normalized 2D relation with knee flexion angle. Center: 3D relation with hip and knee flexion angles. Right: Normalized 2D relation with hip flexion angle. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for hip flexion and black for knee flexion. Notice the curves may be divided into two groups, distinguished by the angle of zero-moment, as indicated by the red dashed line and arrows.

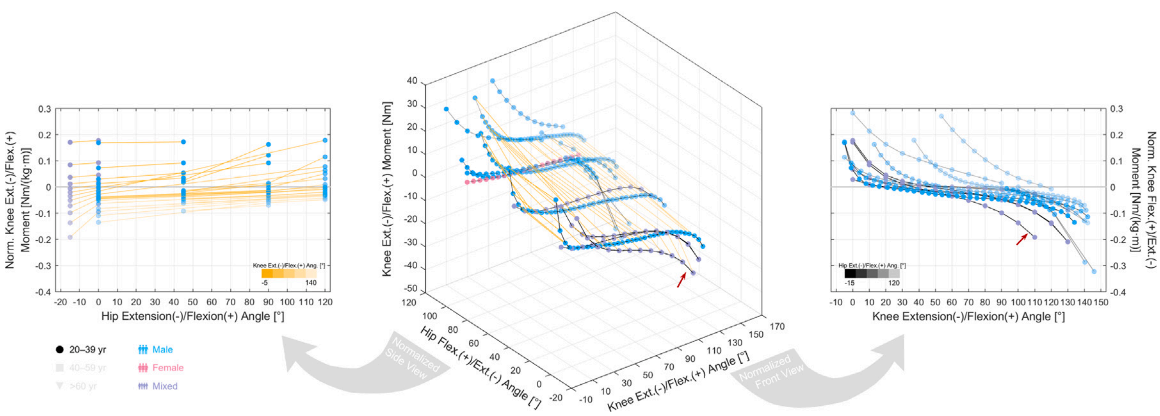

Fig. 3. Relations of passive knee extension/flexion moments. Left: Normalized 2D relation with hip flexion angle. Center: 3D relation with knee and hip flexion angles. Right: Normalized 2D relation with knee flexion angle. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for knee flexion and black for hip flexion. Notice the curve pointed by the red arrow is not plotted in the plane of 0° hip flexion, hence differs from other curves with little color transparency.

and color of the scatters: circle (20–39 yr), square (40–59 yr), triangle (≥60 yr), red (>80% female), blue (>80% male), purple (mixed). If the angles for the secondary DoF are not specified in the original study, the dataset is only plotted in 2D, with dotted line(s) and unfilled scatters. Note that some datasets are not normalized and shown in 2D plots if subject height and weight are not specified in the original work. Fig. 12 shows the measurement frequency of isometric moments in the sagittal plane.

4. Discussion

4.1. Study heterogeneity

Before looking at the results in detail, we begin with the heterogeneity in the collected studies to explain for some of the variations observed in the moment datasets.

It is well-accepted that muscle strength is related to sex, age, and weight. Thus in the 2D plots, we normalized the moment data against the product of subject height and weight to decrease the range of variation (Handsfield et al., 2014). Although sex- and age-correlations are not a focus of this study, we labeled the curves with subject sex and age, as they might be associated with the variation in the normalized results. Also, we included datasets obtained from professions related to physical performance, but note that practicing such a profession could change the kinetic characteristics (Cometti et al., 2001; Moltubakk et al., 2018; Oliveira and Gonçalves, 2009; Ueno et al., 2018). For clarity of the figures, we did not include this information in the plots but it is recorded in the metadata.

Some other parts of the variation may come from the experiment apparatus and protocol. Before the prevalence of commercial dynamometers such as Cybex, Biodex, KinCom, and Isomed2000, researchers customized devices for moment measurement (Marsh et al., 1981; Smidt, 1973; Wiemann and Hahn, 1997), and this variety of apparatus makes it complicated to compare between studies. For instance, perhaps for the consideration of convenience, researchers would use hand-held dynamometers to measure force and calculate moment with manually-measured lever arm, but this method would yield different results compared with the conventional isokinetic dynamometer (Bazett-Jones and Squier, 2020) or if different techniques are used (Krause et al., 2014). Also, the moment induced by gravity is erroneous to the measurement, and researchers take mixed approaches to treating it (Billot et al., 2011; Kellis, 2019; Morris et al., 2021; Salsich et al., 2000). There are more variables in terms of the protocol: e.g., familiarization (Alt et al., 2014; Al-Uzri et al., 2017), lying in supine or prone (Barr and Duncan, 1988; Mańka et al., 2022; Turpin et al., 2014), measurement by side or leg dominance (T'Jonck et al., 1997; Maganaris et al., 1998), discrete or reciprocal isokinetic test (Alt et al., 2024; Svantesson et al., 1994), provision of visual feedback (Hald and Bottjen, 1987), and various ways of stabilization (Alt et al., 2016; Lavin and Gross, 1990; Magnusson et al., 1993; Nisell et al., 1989; Weir et al., 1996a). Even clenching of the teeth or positioning of the tongue are reported to induce significant differences in measurements (di Vico et al., 2013;

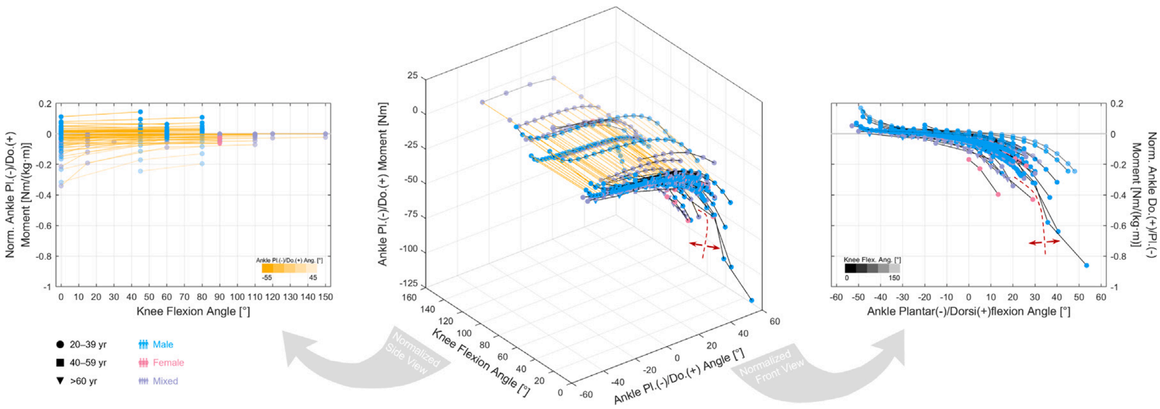

Fig. 4. Relations of passive ankle plantar-/dorsiflexion moments. Left: Normalized 2D relation with knee flexion angle. Center: 3D relation with ankle dorsiflexion and knee flexion angles. Right: Normalized 2D relation with ankle dorsiflexion angle. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for ankle dorsiflexion and black for knee flexion. Notice the curves may be divided into two groups, distinguished by the angle of zero-moment, as indicated by the red dashed line and arrows.

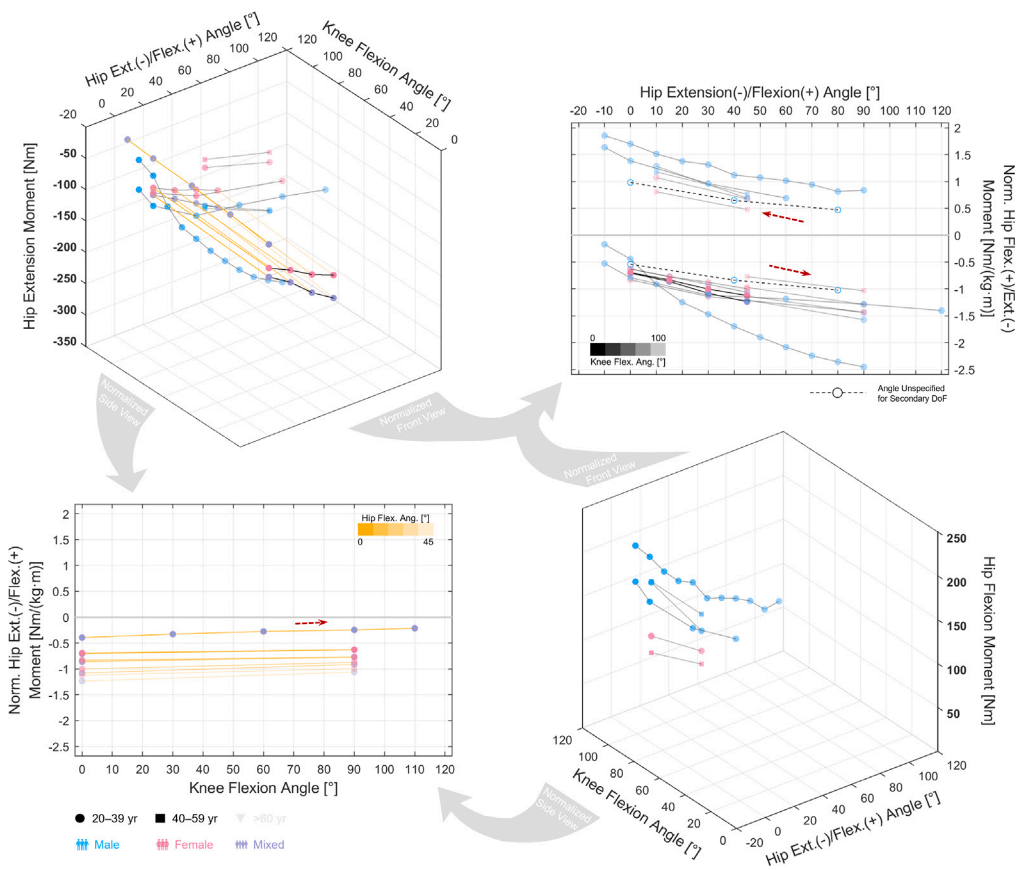

Fig. 5. Relations of isometric hip extension/flexion moments. Top left: 3D relation of extension moment with hip and knee flexion angles. Top right: Normalized 2D relation with hip flexion angle. Bottom left: Normalized 2D relation with knee flexion angle. Bottom right: 3D relation of flexion moment with hip and knee flexion angles. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for hip flexion and black for knee flexion. The direction of muscle stretch is indicated by the red arrows.

Sasaki et al., 1998). Importantly, the center of rotation is critical as it directly affects measurement accuracy, but how this center is determined is not typically described, and one can expect miscellaneous approaches from studies. It is also worth noticing that the center of rotation is not necessarily fixed during motion (Rugg et al., 1990; Tsaopoulos et al., 2009; Yamaguchi, 2001), and it could be well-aligned to the apparatus at rest but misaligned once muscles activate (Alt et al., 2023; Arampatzis et al., 2007; Chiu et al., 2022). For more details of the considerations (e.g., gravity correction, familiarization, and axis alignment) in joint moment measurement, see also Baltzopoulos (2007) and Gleeson and Mercer (1996).

For most part, the datasets we gathered inevitably suffer from the impact of the factors mentioned above as well as many not mentioned, and the curves plotted in Figs. 2–11, 13–16 are not particularly consistent in terms of the magnitude. Our meta-visualization serves as a reminder of the potential errors in individual studies and offers a more general reference for those who wish to perform biomechanical analysis with moment data. As will be shown in later discussion, it is easy to

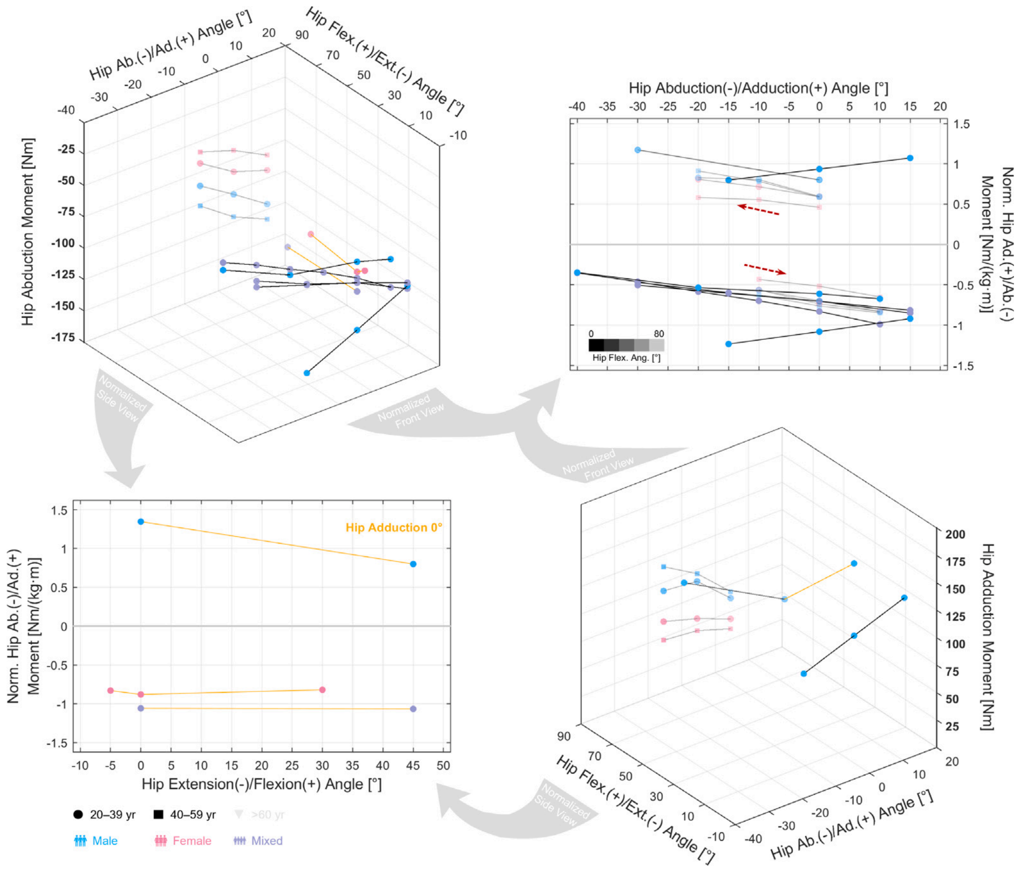

Fig. 6. Relations of isometric hip ab-/adduction moments. Top left: 3D relation of abduction moment with hip adduction and flexion angles. Top right: Normalized 2D relation with hip adduction angle. Bottom left: Normalized 2D relation with hip flexion angle. Bottom right: 3D relation of adduction moment with hip adduction and flexion angles. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the black curve segment denotes hip flexion angle (color bar). The direction of muscle stretch is indicated by the red arrows.

end up in distinct conclusions when only a few datasets are used in the representation of joint kinetic characteristics.

4.2. Passive moment

Passive moment is an elementary kinetic property in the joint: Its exertion is mostly mechanical, hence easy to measure, and it is also part of the *total* moment measured with activated muscles, so it is often corrected for when studying active mechanics.

In the lower limb, most of the datasets we gathered are for the sagittal plane, especially ankle plantar-/dorsiflexion (Table 2). Lower limb motion in the sagittal plane has been a major interest in the biomechanics community, for their dynamics are more dominant in daily locomotion such as walking and running, and the dynamometers used to measure joint moment are generally designed to have the subjects stabilized in the sagittal plane. So it is natural that researchers tend to report sagittal moment data. Especially considering that the RoM and muscle moment arm are generally larger in the sagittal plane (Chen and Franklin, 2024), the stretch of passive components will be more intensive, thus it is more necessary and convenient to measure the passive moment.

The pattern of passive moment–angle relation is simple, because it mainly depends on the mechanical stretch of muscles in different joint positions. In theory, there should be an increase of extension moment as the joint flexes and an increase of flexion moment as the joint extends. Meanwhile, due to the existence of biarticular muscles such as the rectus femoris, hamstrings, and gastrocnemii, this rule is reversed for the adjacent joint: there should be an decrease of extension moment as the adjacent joint extends and an decrease of flexion moment as the adjacent joint flexes.

We start from the passive moment–angle relations in the secondary DoF (Figs. 2–4, left), that is how the passive moments in the hip, knee, and ankle change according to joint angles at the knee, hip, and knee. In the hip, although only two studies contain relevant data, we can still see a decrease of hip extension moment or an increase of hip flexion moment as the knee flexes, especially evident when hip is highly extended or flexed (Fig. 2, left). A similar pattern is observed in the knee, but with a smaller magnitude (Fig. 3, left); this could be because the difference of biarticular muscles in their moment arms about the hip and knee (Chen and Franklin, 2024). In the ankle, the decrease of plantarflexion moment along the increase of knee flexion is evident when the ankle is dorsiflexed (Fig. 4, left), and such decrease is caused by the gastrocnemii, which are less stretched as the knee flexes. Since the gastrocnemii constitute about one third of the triceps surae (Handsfield et al., 2014; Ward et al., 2009), they likely contribute to one third of the passive moment when they are equally stretched as the soleus, and this portion will reduce when the knee becomes highly flexed (imagine loosening one of the three parallel springs), consistent with the magnitude shown in Fig. 4 (left).

In the primary DoF, the pattern in the passive moment–angle curves is, as expected, generally exponential (Figs. 2–4, center and right), but this simple pattern causes an issue in the precise depiction of passive moment–angle relations. For example in Fig. 2 (right), looking at the hip moment–angle curves with non-transparent colors (extended knee), it is easy to distinguish two groups: the *left* group starts from no moment at the neutral hip position to a maximum of 0.4 N m/(kg m) at 50° hip flexion, while the *right* group has a zero-moment angle of 20°–30° and reaches a similar maximum only at 100° hip flexion. This disparity is well worth noticing, because it is not just a shift in the zero-moment angle but really about how much passive moment is exerted by

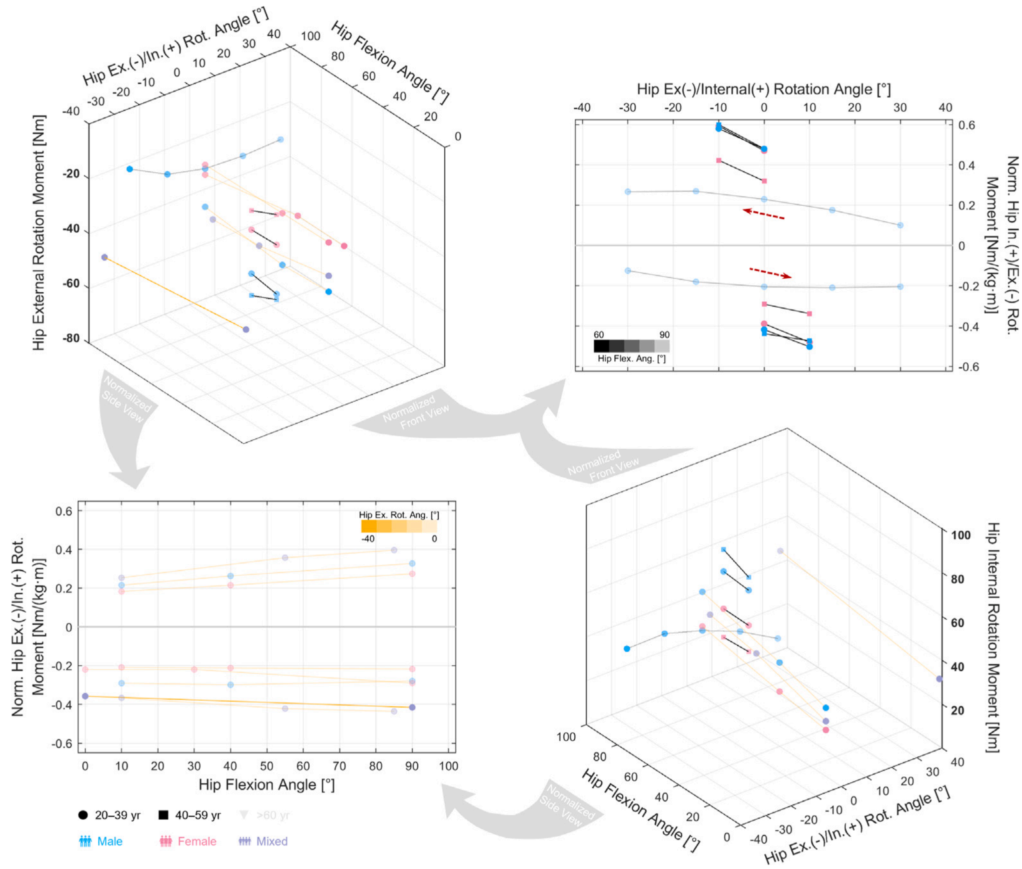

Fig. 7. Relations of isometric hip ex-/internal moments. Top left: 3D relation of external rotation moment with hip internal rotation and flexion angles. Top right: Normalized 2D relation with hip internal rotation angle. Bottom left: Normalized 2D relation with hip flexion angle. Bottom right: 3D relation of internal rotation moment with hip internal rotation and flexion angles. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for hip external rotation and black for hip flexion. The direction of muscle stretch is indicated by the red arrows.

the hip in high flexion positions: Since passive moment increases much more as the joint approaches the end of RoM, if the joint is positioned with even a small error (e.g., hip over-flexed to 95° instead of 90°), passive moments measured at the latter half of RoM may contain large errors; imagine shifting an exponential curve horizontally.

One reason behind such discrepancy could be the way researchers positioned the subjects in the so-called "neutral position", which is usually supine. Wiemann and Hahn (1997) placed a "supporting jack" under the subject's sacrum, which could have anteriorly tilted the pelvis when the thigh appeared to be in line with the trunk. If so, the measurement may have in fact started from a slightly flexed hip angle rather than zero, inducing a left shift of the curve. Miyamoto et al. (2017) had the subjects lying on their side, where the pelvis might no longer be posteriorly tilted by the weight of the spine and the back muscles, and the curve would shift similarly to the previous example. For gravity correction, Halbertsma et al. (1999) subtracted from all data the measurement in the neutral position as the moment induced by limb and apparatus weight, which assumes no passive moment in the neutral position. However, some studies reported flexion moment up to 10 N m (Riener and Edrich, 1999; Silder et al., 2007), hence the curve might be shifted downwards, visually inducing a left shift.

A similar issue is observed in passive ankle plantar-/dorsiflexion moment curves (Fig. 4, center and right). Unlike the hip or knee, there lacks a natural neutral position for the ankle, and the ankle angle is usually define as the included angle between the tibia and the sole of the foot. However, the tibia has thickness and is not a line, so there will be significant differences depending on whether the length axis is chosen as the anterior border (Toft et al., 1989), the posterior border (Marsh et al., 1981), the connection between the fibular head and medial malleolus (Weiss et al., 1986), or by some other standards. Furthermore, the RoM of ankle plantar-/dorsiflexion is much smaller than that of the hip and knee, so even a small variation of 10° would appear huge for the passive moment–angle curve. Similar to hip extension/flexion, in Fig. 4 (right), there is a *right* group of passive plantar-/dorsiflexion moment–angle curves (Savage et al., 2015), with no passive moment in the neutral position, and a *left* group, reporting a zero-moment angle of 10°–15° plantarflexion (Toft et al., 1989; Winegard et al., 1997).

In comparison, the knee is free of this issue, because full extension serves as the neutral position and the extent of hyperextension is small compared with the large RoM of knee extension/flexion. In Fig. 3 (middle and right), the seemingly unmatched curves are mainly the results of different hip angles, and the curves in the 3D plot are magnitude-wise consistent in their respective *xz*-planes.

Notably, since passive moment has a lower magnitude compared with active moment, it is more susceptible to additional moment induced by gravity or undesired muscle activation. As previously mentioned, there is a mixed ways of gravity correction: e.g., estimate gravitational moment using a model (Barber et al., 2011; Riener and Edrich, 1999), reset the force sensor with the limb placed in the apparatus (Miyamoto and Oda, 2003; Morris et al., 2021) or without (Salsich et al., 2000), or subtract the moment measured at rest (Billot et al., 2011; Halbertsma et al., 1999). These approaches have different efficacy in eliminating gravitational moment as well as preserving elastic moment, making it an issue to determine the zero-moment angle. Also, when stretched to a certain extent, tonic stretch reflex may be induced, resulting in a significant increase in the measured moment (Wiemann

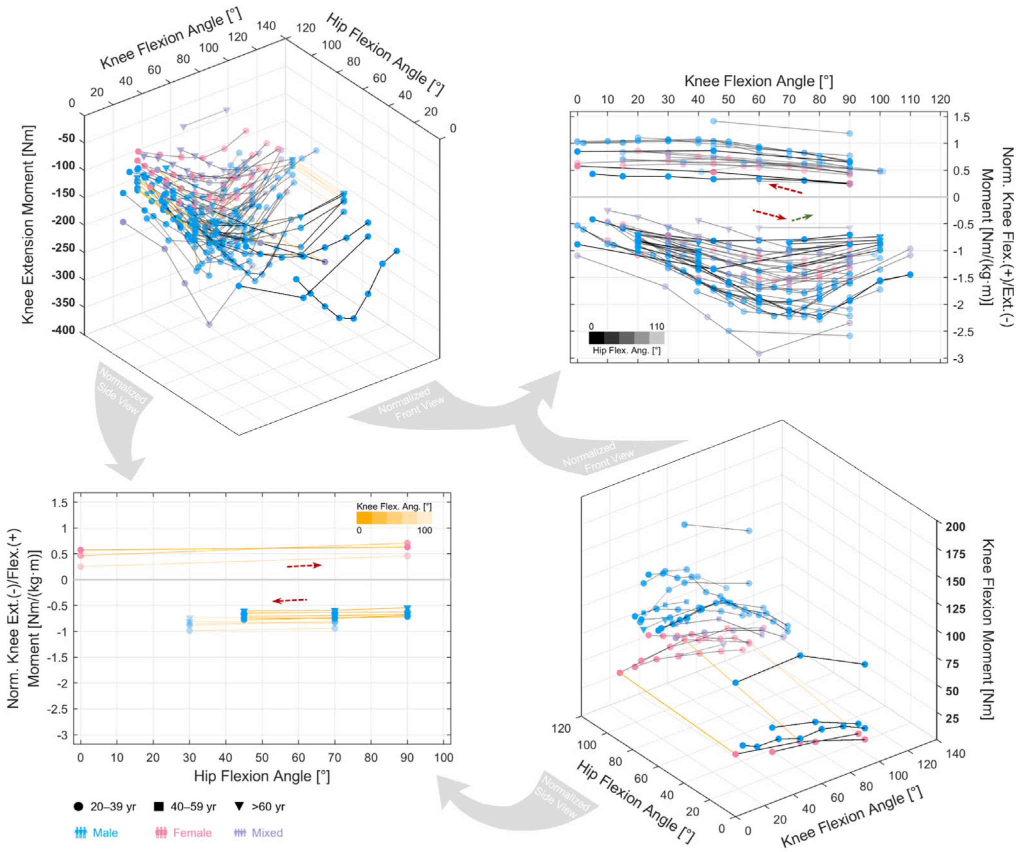

Fig. 8. Relations of isometric knee extension/flexion moments. Top left: 3D relation of extension moment with knee and hip flexion angles. Top right: Normalized 2D relation with knee flexion angle. Bottom left: Normalized 2D relation with hip flexion angle. Bottom right: 3D relation of flexion moment with knee and hip flexion angles. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for knee flexion and black for hip flexion. The direction of muscle stretch is indicated by the red arrows.

and Hahn, 1997) and potentially an overestimation of elastic properties. These limitations should be noted when passive moment datasets are used.

4.3. Isometric moment

It is well-known from the muscle force–length relation that maximal muscle force varies with muscle length, and there is an optimal length where maximal muscle force reaches its peak. Hence it is reasonable to expect a similar shape for the joint moment–angle relation, where there is also a peak value and an accordant optimal joint angle.

Nevertheless, based on our gathered datasets, although maximal joint moment does operate on the ascending limb, a plateau is not typically reached and it can be hard to identify a peak value. Overall, the moment–angle curves in the primary DoF exhibit a similar pattern: When the data for two directions of a DoF are plotted together, the two groups of curves are visually similar to an equal sign rotated clockwise (Figs. 5–9, top right). In other words, the maximal moment exerted in either direction of a DoF increases as joint angle increases along the other direction, where the agonists are lengthened; we refer to it as *parallel ascend*. This is not at all a new finding but rather easily expected. When a joint approaches full extension, there should be less need to further extend the joint, because there simply is no more space for extension, and it should be more likely that flexion is to be initiated; otherwise human kinematics would easily get stuck in some extreme position. However, it is unclear how much of this is attributed to active contraction, since passive correction is absent in many of the collected studies. For instance, when passive corrected, it seems that more plantar-/dorsiflexion moment curves are reaching a plateau compared with those without (Figs. 9 and 10, top right). With further experimentation, we may then see if the mechanism of this parallel descent is of neuromuscular or mechanical origin.

For hip extension/flexion, when normalized against subject height and weight, the magnitude of moment is rather consistent between studies (Fig. 5, top right): Hip flexion moment is 1.5–2.0 N m/(kg m) in extended and slightly flexed positions, and decreases below 1.0 N m/(kg m) as the hip flexes. Hip extension moment is 1.0–1.6 N m/(kg m) in highly flexed positions, and decreases below 1.0 N m/(kg m) as the hip extends; Anderson and Pandy (1999) reported extension moment exceeding 2.0 N m/(kg m) in flexed positions, but the pattern is the same. In a similar fashion, hip adduction moment increases as the hip abducts, while abduction moment increases as the hip adducts (Fig. 6, top right); with the exception of Anderson and Pandy (1999). Hip internal moment increases as the hip externally rotates, while external moment increases as the hip internally rotates (Fig. 7, top right).

For knee flexion and ankle dorsiflexion, the ascent is less obvious (Figs. 8 and 9, top right) because their magnitudes are much smaller than those of their counterparts, but it can be well observed when plotted alone, as shown in Figs. 8 and 9 (bottom right). For knee extension, a peak at 60°–80° is observed, beyond which extension moment decreases, and the magnitude of this peak is 1.0–2.0 N m/(kg m). For ankle plantarflexion (Fig. 8, top right), though the ascent is clear, the maximal moment in high dorsiflexion positions is 0.5–1.5 N m/(kg m), and several curves even reach 2.0 N m/(kg m). This variance is much larger than measurements in knee extension, and the conclusion stands even when passive moment are accounted for (Fig. 10). One reason could be the aforementioned issue of the neutral position: Since there is a large error in determining the zero ankle angle, the moment–angle curve may be shifted horizontally.

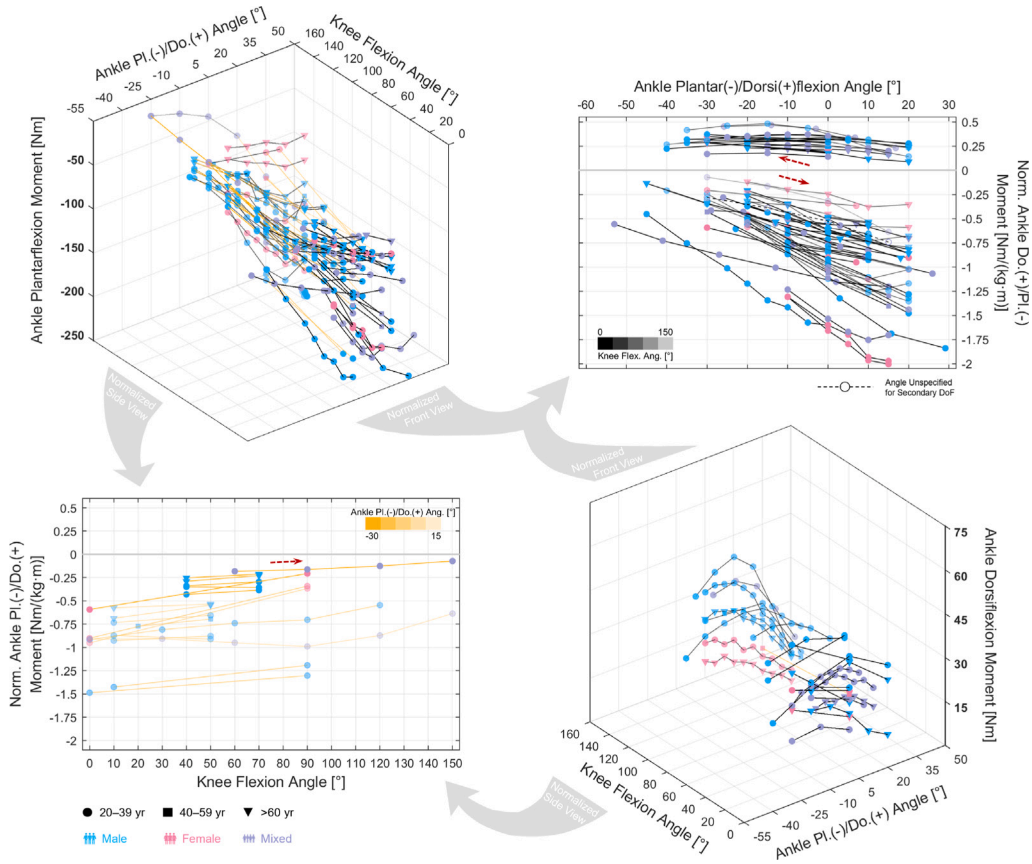

Fig. 9. Relations of isometric ankle plantar-/dorsiflexion moments. Top left: 3D relation of plantarflexion moment with ankle dorsiflexion and knee flexion angles. Top right: Normalized 2D relation with ankle dorsiflexion angle. Bottom left: Normalized 2D relation with knee flexion angle. Bottom right: 3D relation of dorsiflexion moment with ankle dorsiflexion and knee flexion angles. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for ankle dorsiflexion and black for knee flexion. The direction of muscle stretch is indicated by the red arrows.

As explained, measurements of joint moment may be influenced by a vast range of factors, and for this reason we try not to judge if a dataset is correct. However, it is still possible, and necessary, to evaluate if some are less reliable. Unlike density of blood cells or length of a sarcomere, maximal moment of a joint is not entirely a physical property whose magnitude requires direct measurements to determine. Ultimately, joint moment is for generating kinematics, and the moment required to generate simple locomotion is a bottom line for maximal moment output. For example, based on the kinematics of walking at normal speed (the method of inverse dynamics), it is calculated that a plantarflexion moment of 1.0–1.5 N m/kg (Camargo et al., 2021), or roughly 0.6–0.9 N m/(kg m), is required in the push-off phase, where the ankle is dorsiflexed. Therefore it is fair to question a dataset if the maximal plantarflexion moment measured in dorsiflexed positions is within or below this range estimated during walking, especially if healthy young subjects were tested.

This in part justifies our exclusion of data fitted in more than two dimensions (Fig. 1). Fitting a group of data into a 3D surface would inevitably smooth its peaks, and the results would risk contradicting the kinematics. For example, when fitting moment data to a joint angle–velocity surface, Anderson et al. (2007) estimated a maximal isometric plantarflexion moment of 95 N m for their young subject group, roughly equivalent to 0.7 N m/(kg m). This value is barely enough for walking and completely insufficient for running (1.2 N m/(kg m); Fukuchi et al., 2017). If this dataset is used to calibrate a musculoskeletal model, even the simulation of locomotion may not be accurate. Hence, despite the labor-intensive experiments and valuable discoveries, the work of Anderson et al. (2007) and others (Khalaf et al., 2000; Hussain and Frey-Law, 2016; Marshall et al., 1990) are not included in this study.

Although our proposed method of comparing estimates of maximal joint moments to those required for locomotion is simple and straightforward, we do not recommend using more intensive movements, such as jumping and squatting, as a more strict criterion for filtering. On the one hand, the method of inverse dynamics might overestimate joint moment for reasons such as misconfigured joint rotation center or inaccurate ground reaction force. On the other hand, in isometric experiments, although subjects are instructed to contract their agonists as much as possible, the activation of agonists is not necessarily maximal (Arampatzis et al., 2006b; Kennedy and Cresswell, 2001; Rassier and Minozzo, 2016), nor is the activation of antagonists necessarily zero (Aagaard et al., 2000; Billot et al., 2011; Kellis and Baltzopoulos, 1997; Maganaris et al., 1998). It could be that the measurements obtained in a lab are always lower than the theoretical maximal isometric moment, and too high a threshold would underestimate the reliability of many experiments properly conducted. Moreover, we emphasize that the aforementioned datasets are not excluded because the maximal value is below certain inverse dynamics–based estimate, but rather because the peaks are likely reduced from fitting in a surface.

Regarding the relations of moments in the sagittal plane (Figs. 5, 8, 9, bottom left) in the secondary DoF, the pattern is similar to that exhibited in passive moment relations (Figs. 2–4, left) and appears to be in *parallel descent* when plotted together (Fig. 8, bottom left). For example, maximal isometric plantarflexion moment decreases as the knee flexes (Fig. 9, bottom left), since the shortening of the gastrocnemii not only decreases their passive force but also brings active force down in the ascending limb of force–length curve (Herzog et al., 1991; Maganaris, 2003) or due to neural regulation (Arampatzis et al., 2006b; Kennedy and Cresswell, 2001). For moments in the non-sagittal planes, there are not enough data to draw any conclusions, but we do not expect to

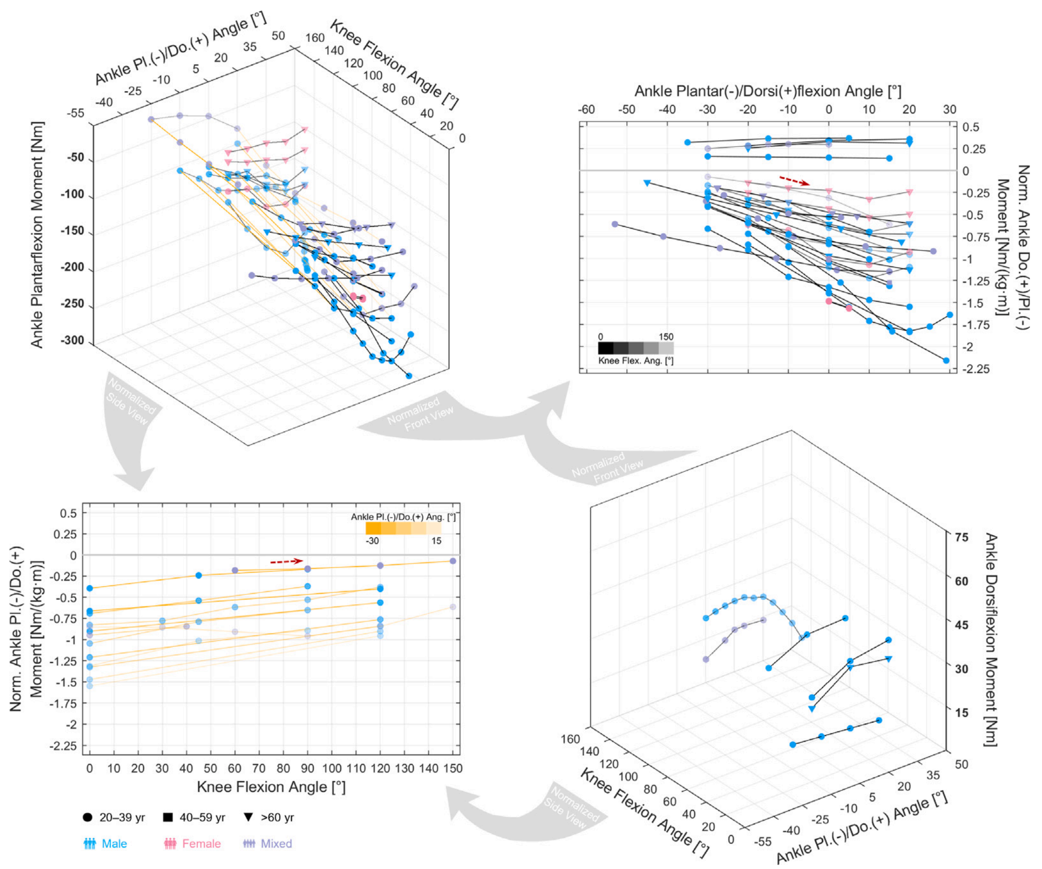

Fig. 10. Relations of isometric ankle plantar-/dorsiflexion moments (passive corrected). Top left: 3D relation of plantarflexion moment with ankle dorsiflexion and knee flexion angles. Top right: Normalized 2D relation with ankle dorsiflexion angle. Bottom left: Normalized 2D relation with knee flexion angle. Bottom right: 3D relation of dorsiflexion moment with ankle dorsiflexion and knee flexion angles. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the angle in the relatively fixed DoF (color bar): with yellow for ankle dorsiflexion and black for knee flexion. The direction of muscle stretch is indicated by the red arrows.

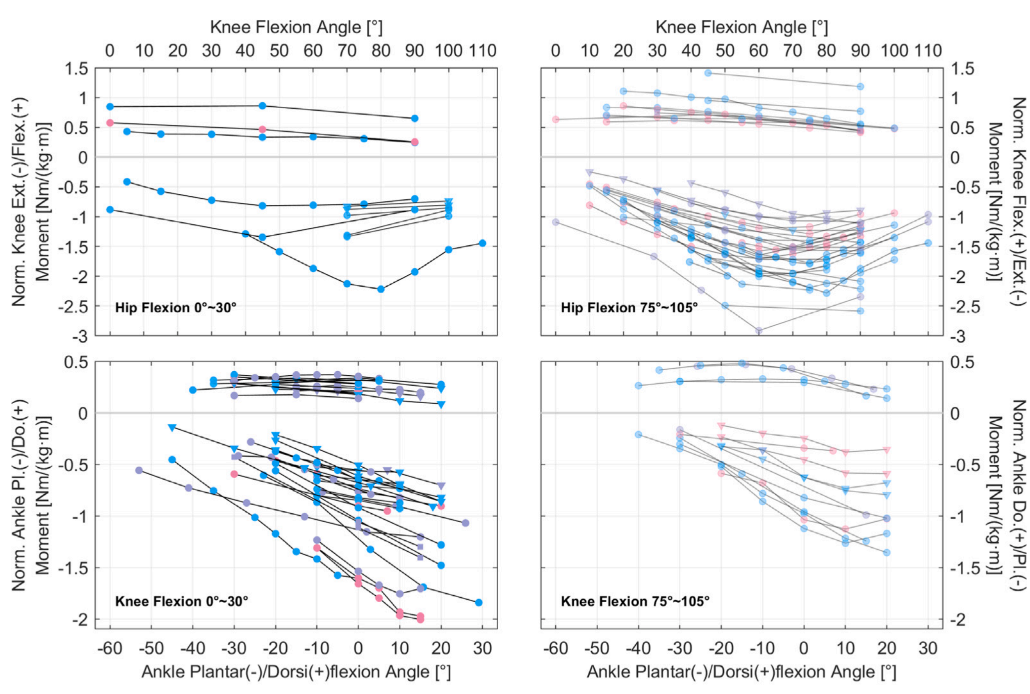

Fig. 11. Relations of isometric knee extension/flexion and ankle plantar-/dorsiflexion moments with respective angles. Top left: Relation of knee moments when the hip is extended or slightly flexed. Top right: Relation of knee moments when the hip is highly flexed. Bottom left: Relation of ankle moments when the knee is extended or slightly flexed. Top right: Relation of ankle moments when the knee is highly flexed. Data are normalized by the product of subject height and weight.

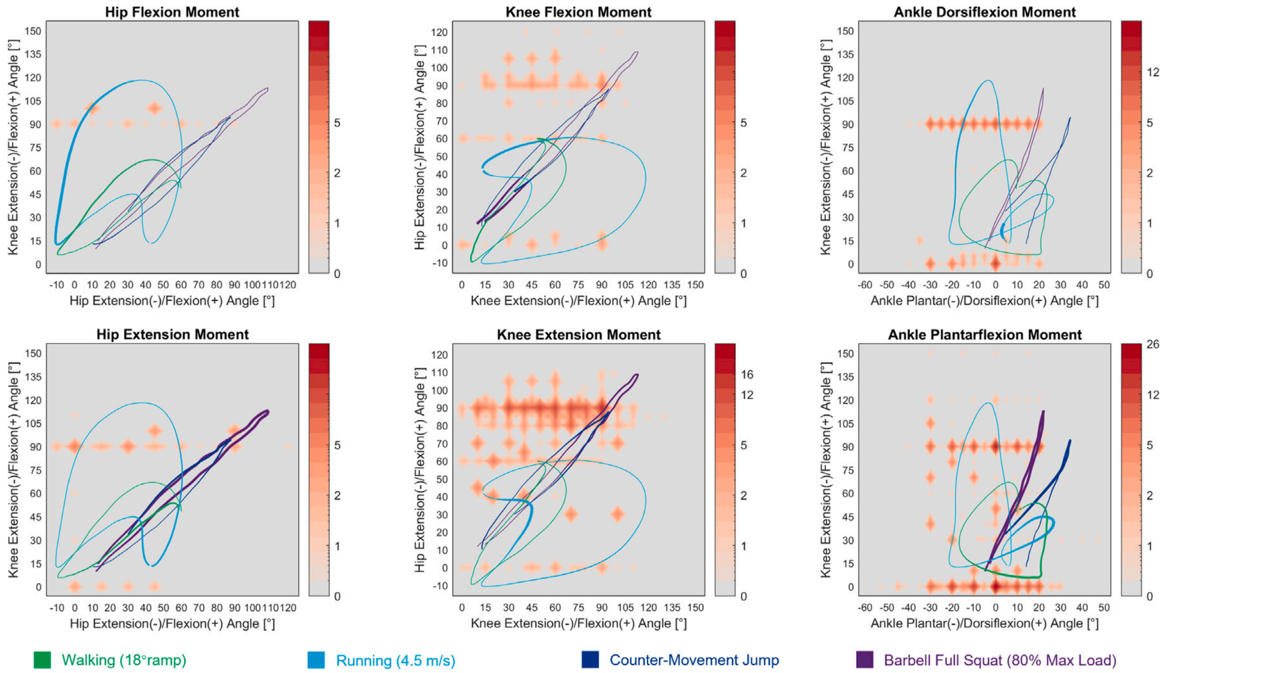

Fig. 12. Measurement frequency of isometric moments in the sagittal plane. The color assigned for each joint position denotes the number of studies that performed isometric measurements at this position (color bar); e.g., 26 studies measured ankle plantarflexion moment at the position of 0° ankle dorsiflexion and 0° knee flexion. The colored curves denote the kinematics of dynamic motions, and the moment required at each position is indicated by the thickness of the segment.

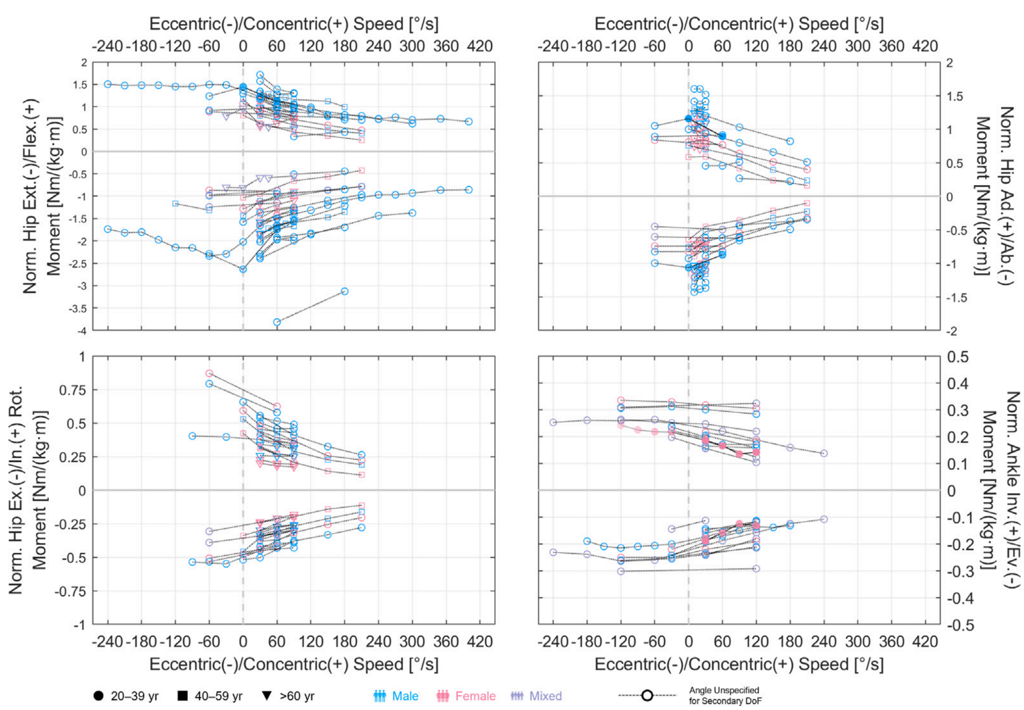

Fig. 13. Relations of isokinetic moments with angular velocity in the hip and ankle. Top left: Hip extension/flexion. Top right: Hip ab-/adduction. Bottom left: Hip ex-/internal rotation. Bottom right: Ankle eversion/inversion. Data are normalized by the product of subject height and weight.

see parallel descent. This is because, unlike in the sagittal plane where biarticular muscles have opposite functions in the adjacent joints, the functions of a muscle in the sagittal and non-sagittal planes are not coupled with a pattern. For instance, while both parts of the gluteus maximus function as hip extensors, the upper part is a hip abductor while the lower part is a hip adductor (Eng et al., 2015). The gluteus medius is a hip abductor, and its anterior part is a hip flexor while its posterior part is an extensor (Beck et al., 2015). Thus, without sufficient measurements, it remains unclear how moments in the non-sagittal planes would change due to the motion in the sagittal plane.

Finally, to have a full picture of the joint positions well explored of their isometric capacities, we plotted a heat map of measurement frequency (Fig. 12): Joint positions that frequently get measured in isometric experiments are plotted with larger and redder patches. It is evident that most of the measurements are for knee extension and ankle plantarflexion moments, and they are also limited to a few joint

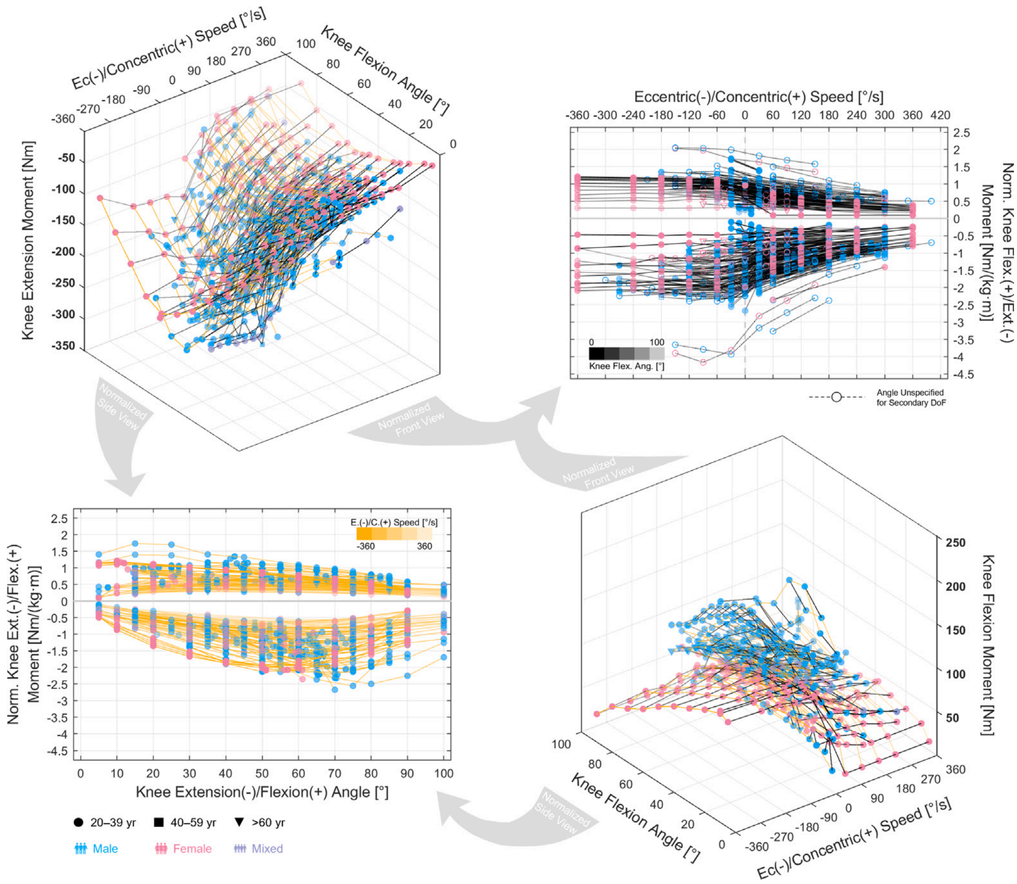

Fig. 14. Relations of isokinetic knee extension/flexion moments. Top left: 3D relation of extension moment with angular velocity and angle. Top right: Normalized 2D relation with angular velocity. Bottom left: Normalized 2D relation with angle. Bottom right: 3D relation of flexion moment with angular velocity and angle. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the value in the relatively fixed DoF (color bar): with yellow for angular velocity and black for knee flexion angle.

positions; e.g., knee moment at various knee angles with 90° hip flexion, ankle moment at various ankle angles with 0° and 90° hip flexion. Furthermore, to denote the importance of each joint position, we included the kinematics of incline walking (Camargo et al., 2021), running (Fukuchi et al., 2017), counter-movement jump (Raffalt et al., 2016), and loaded full squat (Robertson et al., 2008), with indication of the moment required along the process. The rationale is that, the joint positions covered by these curves are *functional positions* that routinely occur in daily tasks, which we consider more superior in the joint space.

For accurate biomechanical analysis, moment measurements should be conducted in such functional positions or positions with specified considerations rather than convenient positions in laboratory environments such as sitting and lying. However, it is rather clear that current measurements cover little of the region that these curves pass through. For example, hip flexion moment is mostly required between the mid-stance and mid-swing phases of running, where hip flexion is between -10°–30° and knee flexion between 15°–120°. In Fig. 12 (top left, cyan curve), in the far left region of the plot where this part of the curve locates, only a few patches are lit up. This means that the available data are insufficient to support accurate biomechanical analysis for running. For more intensive motions such as jumping and squatting, there is a simultaneous increase of hip flexion, knee flexion, and ankle dorsiflexion angles in the concentric phase and a simultaneous decrease in the eccentric phase, and the curves mainly travel through the diagonal direction of the plots. Nevertheless, the majority of this region has no measurement at all, and when measurements do exist, they are often from separate studies with potentially large variations in the data. Lacking constructive moment data in these function positions, it can be hard to deduce the moment–angle relation for further analysis. In a more practical perspective, the collected datasets are essential in calibrating the kinetics of musculoskeletal models, but without enough moment data in varied joint configurations, the calibration may only remain valid for a limited RoM (e.g., walking) and simulation accuracy will be capped. In this sense, Fig. 12 could be useful to design experiments for effective measurement.

4.4. Isokinetic moment

A key point to notice in isokinetic moment datasets is how the data are obtained: As mentioned in the Methods section, they are different in whether the moment is the angle-specific, peak, or mean value during the tested RoM. Due to the moment–angle relation, the curves plotted based on these values would obviously be different in magnitude, but it remains unclear to many if measurements from different joint angles, when normalized against maximal isometric moment, would lead to the same moment–velocity relation. In other words, is the force–velocity relation length-dependent?

To answer this question, we may start from Hill's (1938) famous experiment of shortening heat and dynamic constants, and see if his experiment falls into the category of length-specific, peak, or mean. Here, it must be noted that the relation Hill (1938) revealed is between constant load and mean velocity throughout an isotonic contraction, which is slightly different from the current muscle force–velocity relation. Also, there was no discussion over how muscle length would influence the results; in fact, based on Hill's (1938) description, some of the tests clearly involved muscle contracting at non-optimal lengths. Nevertheless, as technology advances, it was demonstrated with force transducers that a similar relation holds for muscle force and instant

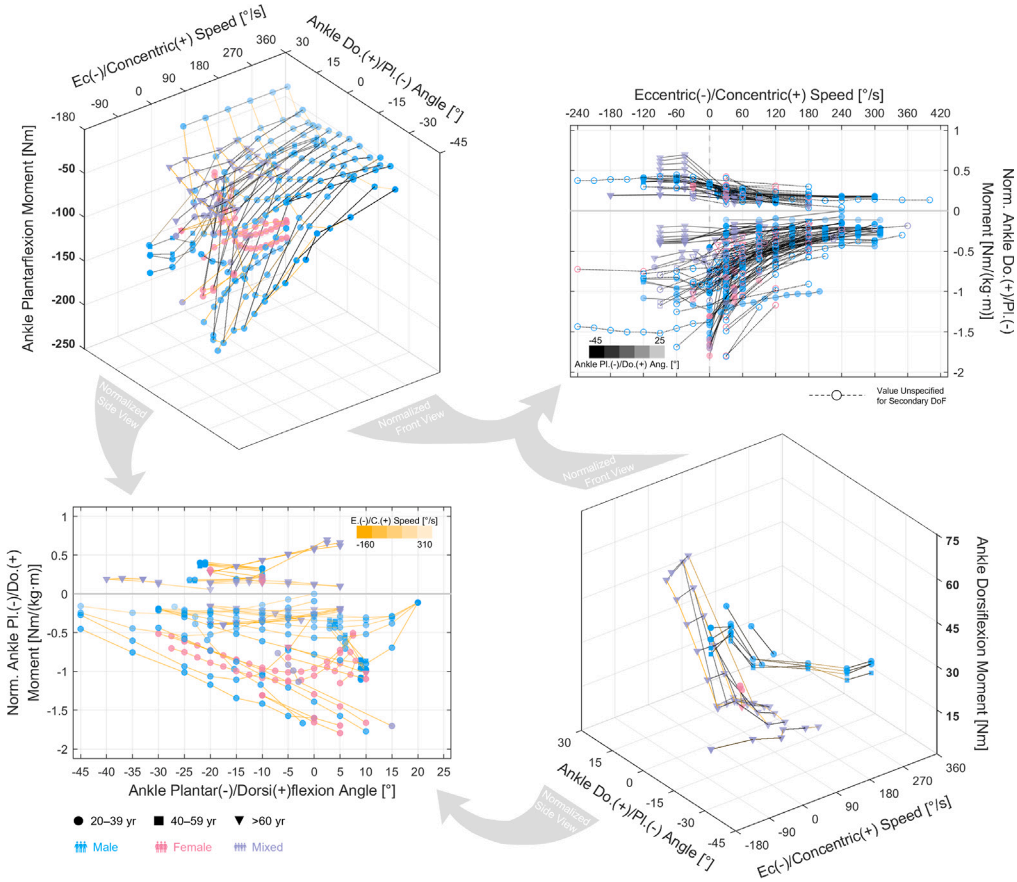

Fig. 15. Relations of isokinetic ankle plantar-/dorsiflexion moments. Top left: 3D relation of plantarflexion moment with angle and angular velocity. Top right: Normalized 2D relation with angular velocity. Bottom left: Normalized 2D relation with angle. Bottom right: 3D relation of dorsiflexion moment with angular velocity and angle. Data are normalized in the 2D plots by the product of subject height and weight. The transparency of the curve segment denotes the value in the relatively fixed DoF (color bar): with yellow for angular velocity and black for ankle dorsiflexion angle.

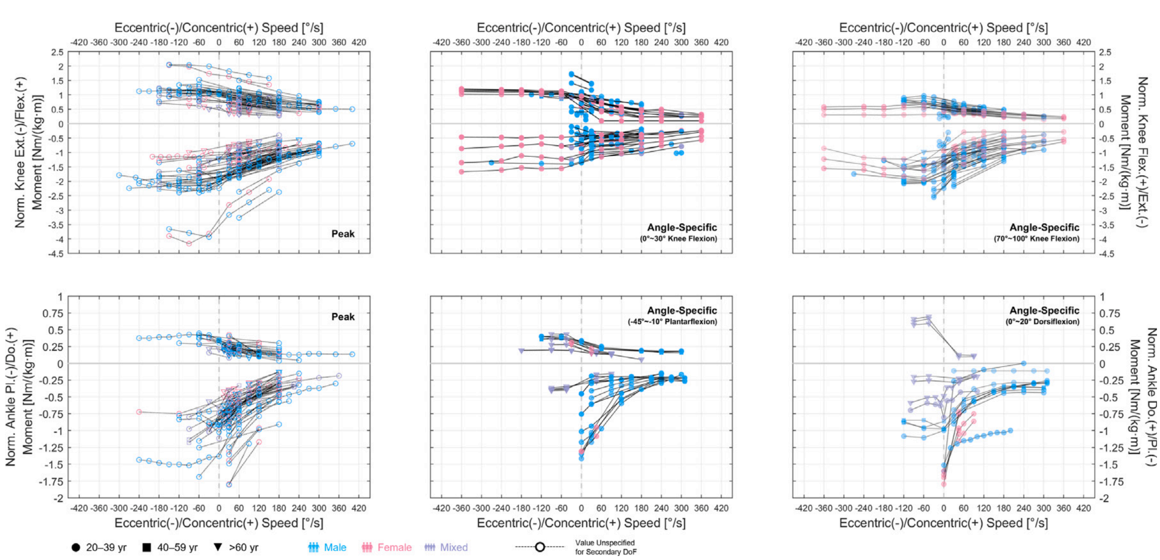

Fig. 16. Relations of isokinetic knee extension/flexion and ankle plantar-/dorsiflexion moments with angular velocity. Top left: Relation of knee moments based on peak values. Top center: Relation of knee moments based on angle-specific values. Top right: Relation of knee moments based on angle-specific values from small knee flexion angles. Bottom left: Relation of ankle moments based on peak values from large knee flexion angles. Bottom center: Relation of ankle moments based on angle-specific values from ankle plantarflexion angles. Bottom right: Relation of ankle moments based on angle-specific values from zero or ankle dorsiflexion angles. Data are normalized by the product of subject height and weight.

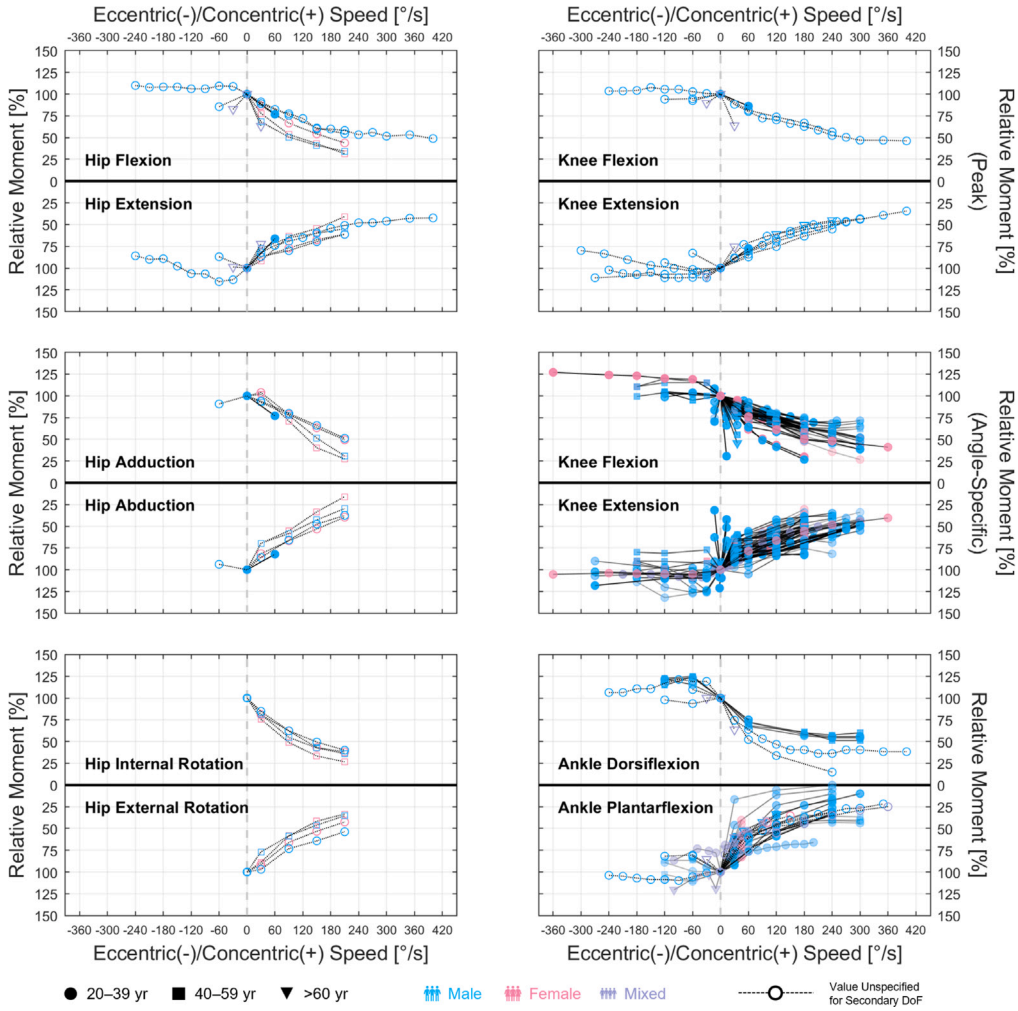

Fig. 17. Relations of relative moments with angular velocity. Top left: Hip extension/flexion. Middle left: Hip ab-/adduction. Bottom left: Hip ex-/internal rotation. Top right: Knee extension/flexion, based on peak values. Middle right: Knee extension/flexion, based on angle-specific values. Bottom right: Ankle plantar-/dorsiflexion. Relative moment is calculated with the isometric value. For datasets based on peak values, the isometric value is only considered valid if it is the larger value of measurements obtained from at least two different angles. Otherwise, it is unclear whether the value is the peak isometric moment, and the increase will be overestimated in eccentric contractions while the decrease will be underestimated in concentric contractions.

velocity in both isotonic and isokinetic conditions (Gollapudi and Lin, 2009; Iwamoto et al., 1990; Mashima et al., 1972).

Importantly, it was further demonstrated that the force–velocity relation can be length-dependent in many ways. Mashima (1977) and Krylow and Sandercock (1997) showed that the maximal shortening velocity would decrease if the shortening starts from a length with sufficiently small isometric force. This means the shape of the normalized force–velocity curve might vary for different initial lengths; more specifically, the normalized curve would in general appear steeper if the initial length is sufficiently *unoptimal* (e.g., <90% optimal length). The final length of contraction is also relevant, as muscle would experience force depression: In shortening contraction, muscle force is smaller than its maximal isometric value at the final length even when the velocity reaches zero, and the magnitude of decrease is greater for larger displacement (Herzog et al., 2000). Last but not least, Scott et al. (1996) showed that even in a single isokinetic contraction, regardless of concentric or eccentric, the extent by which force is decreased or increased would vary at different lengths.

Therefore, in isokinetic experiments, it is important that moment data are obtained at specific joint angles, rather than using the peak or mean values as a replacement. It is equally critical to control for the tested RoM to eliminate the influence of initial isometric force and force depression. Nonetheless, it is difficult to have subjects maximally activate at every angle, and many studies measured isokinetic moments merely as an indication of muscle strength for correlation analysis, so the majority of the datasets were recorded with peak values from different RoMs. This induces further variations in the isokinetic moment curves on top of the factors discussed in the Study Heterogeneity subsection.

In the main, the moment–velocity curves are rather chaotic (Figs. 13–16). When normalized against measurements in the isometric condition, the relative moment curves present a pattern similar to the force–velocity relation, but the lower and upper bounds are noticeably different (Fig. 17). In the concentric part of the force–velocity curve, muscle force would decrease to zero when shortening at a maximal velocity, while in the eccentric part, force would increase more than 1.6 times the isometric value (Krylow and Sandercock, 1997; Mashima et al., 1972). As shown in Fig. 17, joint moment does not typically go below 25% in high concentric speeds and rarely reaches over 125% in eccentric conditions. This is a major difference between the characteristics of muscle fiber and the muscle–tendon unit, and may be attributed to several reasons.

First of all, the stretch of the elastic tendon during muscle contraction comprises up to 9.2% of muscle–tendon unit length change (Waugh et al., 2012), which decreases the shortening or lengthening velocity of muscle fascicles. For muscles with large pennation angles, such as the soleus, vastus medialis, and gluteus maximus (Ward et al., 2009), the velocity of muscle fascicles will be further decreased. The existence of connective tissues or the 3D architecture of the muscle may also cause a slow-down. Consequently, the fascicle might be contracting at a much slower speed than when calculated directly from joint rotational speed, and it may not operate on the far left and far right region of the force–velocity curve. Moreover, there could be neurological factors that prevent the exertion of maximal force in isokinetic conditions. Especially with eccentric contractions, subjects require training to get used to the experiment set-up, even still they might feel uncomfortable finishing the task. Then as aforementioned, the activation of agonists and antagonists are not necessarily full and null, and may even vary at different positions (Arampatzis et al., 2006b; Kennedy and Cresswell, 2001; Rassier and Minozzo, 2016), so there is no reason to assume a constant and maximal muscle activation in an isokinetic contraction.

Despite the large variations in the isokinetic moment curves, readers are still encouraged to refer to them in biomechanical analysis. For example, in musculoskeletal modeling, the muscle is generally modeled with predefined force–velocity characteristics. Suppose the joint moment ends up varying from 0%–150%, which is broader than the range suggested by the datasets, muscle activation would be underestimated in eccentric conditions and overestimated in concentric. Thus, it is necessary to validate the modeled moment–angular velocity relation with measurements, in particular if the motions to simulate are highly dynamic.

4.5. Limitations

In order to gather as many relevant datasets as possible, we employed the common techniques in systematic review and worked our way from 8800 research results. Yet it would not be surprising if some of the featured studies are missed out. Joint moment is an ordinary type of data in biomechanical investigations, and its measurement is much more difficult to pin-point compared with the research questions typically addressed with meta-analysis. For this, we took a machine learning–like approach, where the keywords were tuned to ensure search accuracy in a calibration set. The format of the final keyword set is complicated but proves to be efficient: Of the 55 studies containing passive moment datasets, 40 appeared in searches based on keywords intended for the passive condition (73%). For the 117 isometric-related studies, 100 of them appeared in isometric-based searches (85%), while for the 163 isokinetic-related studies, the intended keywords led to 107 of them (66%). Meanwhile, we included searches for moment arm data using simpler keywords as a fail-safe for overfitting, where a study lacking one of the complex keywords fails to show up.

Even still, it is impossible to secure all relevant studies, simply because the field of biomechanics has thrived for decades with countless moment measurements. We are, however, confident that we have gathered the majority of datasets with quality results. When ranked with the frequency and place of appearing in searches, it is shown the bottom-ranked records are less likely to yield a target study: The target rate decreased from 14% in the first quartile of 4353 records to 9%, 6%, and 4% in the second, third, and fourth. Reasonably, we may deduce that no more than a few dozen studies would be added even with double the size of search results.

To accommodate potential amendments, we provide a log with details of the search workflow (see Appendix B), where excluded records are labeled with the relevant data and the reason of exclusion. Readers may easily expand from the current results and gather datasets with other specific needs; e.g., moment in children or people with cerebral palsy. We believe this is by far the largest and most constructive collection of joint moment datasets, and with the advancement of artificial intelligence such as ChatGPT, we hope colleagues in the field will no longer need to manually repeat our work in the future.

Complete as it might be, our datasets do not cover joint moments in knee ab-/adduction, knee ex-/internal rotation, and ankle ex-/internal rotation, which we have predetermined to be insignificant motions. During our research, we have however identified a few studies measuring active moments in these DoFs with customized devices (Cammarata and Dhaher, 2008; Hester and Falkel, 1984; Zhang et al., 2001). Also, we did not discuss over the correlation of joint moment relations with sex, age or profession, which could be of interest to many. The metadata catalog we provide has a detailed record of subject information in each study, and readers may find many studies with a focus on these topics.

Finally, the joint moment relations we illustrate are based solely on datasets gathered from literature, and we did not conduct measurements of our own. Nevertheless, it is indispensable to have a general understanding of currently available datasets before a purposeful experiment can be designed. As shown in Fig. 12, although there are 117 isometric-related studies, the measurements are crowded in positions less related to the kinematics of ordinary movements. With this in mind, we may then design experiments targeting important functional positions, and the results will be of more value for the biomechanics community.

5. Conclusion

A total of 962 datasets of passive, isometric, and isokinetic moment based on human *in vivo* measurements were collected from literature to illustrate joint moment–angle and moment–velocity relations in the hip, knee, and ankle. The overall pattern and magnitude, as well as the frequency of measurement are presented for 12 joint moments from six DoFs. The findings should provide valuable insight into joint kinetics, enhance biomechanical analysis, and improve the design of future experiments for moment measurement.

CRediT authorship contribution statement

Ziyu Chen: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **David W. Franklin:** Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank Dr. Matthew Millard for the useful discussions. This work was supported by the Lighthouse Initiative Geriatronics by StMWi Bayern (Project X, grant no. 5140951).

Appendix A. List of studies and datasets

Table A.1 lists all relevant studies and datasets in this work. The numbers and signs correspond to those in Table 1. The studies are sorted based on the overall search prominence: A study is placed in the front of the list if it appears more frequently and in higher rankings during our keyword-based searches.

Appendix B. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jbiomech.2025.112621. It is also available at https://doi.org/10.6084/m9.figshare.26018563, with potential corrections and updates of the datasets in the future.

Table A.1
Collected studies and datasets

Study	Available dataset(s)															
	Passive					Isometric					Isokinetic					
Smidt (1973)									4±					4±		
Baxter and Piazza (2014)															5−	
Holzer et al. (2020)										5−						
Nelson et al. (2001)														4−		
Harris-Hayes et al. (2014)								3±								
Bobbert and van Ingen Schenau (1990)										5−					5−	
Mohamed et al. (2002)									4+							
Sale et al. (1982)										5−						
Aagaard et al. (2000)														4±		
Danneskiold-Samsøe et al. (2009)											1±	2±	3±	4±	5±	
Willems et al. (2005b)															5±	6±
Maganaris (2003)										5−						
Caldwell et al. (1993)														4±		
Horstmann et al. (1999)														4±	5±	
Yoon et al. (1991)									4±					4±		
Shenoy et al. (2011)									4−							
Kato et al. (2023)		2														
Arampatzis et al. (2006b)										5−						
Knapik et al. (1983)									4±							
Chen et al. (2022)														4±	5±	
Frey-Law et al. (2012)									4±					4±		
Claiborne et al. (2006)											1±	2±	3±	4±		
Sasaki et al. (2014)										5+						
Marsh et al. (1981)										5+						
Tsiokanos et al. (2002)											1−			4−	5−	
Neumann et al. (1988)							2−									
Kwon and Lee (2013)						1−										
Hahn et al. (2011)					5					5−						
Hisaeda et al. (2001)									4−							
Hahn et al. (2014)									4−					4−		
Fletcher and MacIntosh (2018)					5											
Mademli et al. (2004)										5−						
Kaneda et al. (2020)				4												
Poulmedis (1985)											1±	2±		4±	5±	
Şimşek et al. (2016)														4±		
Simoneau et al. (2007)					5					5±						
Guilhem et al. (2011)														4−		
Bohannon et al. (1986)														4±		
Cometti et al. (2001)														4±		
Kubo et al. (2006a)									4−							
Hartsell and Spaulding (1999)																6±
Kindel and Challis (2017)						1−	2−									
Vagner et al. (2019)											1±		3±			
Kawakami et al. (1998b)										5−						
Ateş et al. (2018)										5+						
Murray et al. (1980)									4±					4±		
Arokoski et al. (2002)											1±					
Johnson and Hoffman (2010)								3±								
di Vico et al. (2013)														4±		
Kaminski et al. (1999)																6−
Cresswell et al. (1995)										5−						
Willems et al. (2005a)															5±	6±
Alahmri et al. (2022)											1±	2±				
Poulis et al. (2000)															5±	
Kubo et al. (2001)					5											
Uritani and Fukumoto (2012)								3±								
Anderson and Pandy (1999)						1±	2±		4±	5±						
Blazevich et al. (2009)														4−		
Wiemann and Hahn (1997)	1															
Kawakami et al. (1998a)										5−						
Hald and Bottjen (1987)														4±		
Dirnberger et al. (2012)														4±		
Gallinger et al. (2020)					5					5−						
Jeon et al. (2001)														4−		
Alt et al. (2016)														4−		
Moltubakk et al. (2018)					5					5−					5−	
Suter et al. (1998)									4−							
Barber et al. (2013)					5					5−					5−	
O'Brien et al. (2009)																
Ferri et al. (2003)									4−	5−				4−	5−	
Styf et al. (1995)															5±	
Reeves et al. (2004)									4−							

(continued on next page)

Table A.1 (*continued*).

Study	Available dataset(s)												
	Passive		Isometric					Isokinetic					
Holzer et al. (2023)												5−	
Gravel et al. (1990)												5−	
Finni et al. (2001)						4−							
Weiss et al. (1986)		5											
van Eijden et al. (1987)						4−					4−		
Gajdosik (2002)												5−	
Billot et al. (2011)							5±						
Weir et al. (1996a)											4±		
Cahalan et al. (1989)			1±	2±	3±			1±	2±	3±			
Fugl-Meyer (1981)												5±	
Snook (2001)												5±	6±
Willems et al. (2002)													6±
Koh and Herzog (1995)							5+						
Maganaris (2004)							5+						
Jones et al. (2009)											4±		
Andrade et al. (2016)		5											
Gupta et al. (2004)										3−			
Light and Thorborg (2016)				2+									
Daneshjoo et al. (2013)											4±		
McFaull and Lamontagne (1998)	4												
Alt et al. (2014)											4±		
Alangari and Al-Hazzaa (2004)											4±		
Lemaire et al. (2014)											4−		
Winegard et al. (1997)		5					5−						
Beynnon et al. (2001)												5±	6±
Rousanoglou et al. (2010)						4−							
Heerkens et al. (1985)	4												
Kellis et al. (2017)											4+		
Müller et al. (2007)													
Gerrits et al. (2003)						4−							
Pang and Mak (2012)												5±	
Horstman et al. (2009)						4±							
Kaufman et al. (1995)											4±		
Hahn (2007)											4±		
Jeon et al. (2016)											4±	5±	
Oliveira et al. (2012)											4±		
Fouré et al. (2009)													
Salzman et al. (1993)						4−							
Cheng and Rice (2013)		5					5+						
Donatelli et al. (1991)									2±				
Atabek et al. (2009)											4±		
Freitas et al. (2013)	4												
Arnold et al. (1996)											4−		
Kordi Yoosefinejad et al. (2022)												5±	6±
Wu et al. (2013)											4±		
Colliander and Tesch (1989)											4±		
Drazan et al. (2019)												5−	
Abellaneda et al. (2009)		5											
Fowles et al. (2000)							5−						
Ekdahl and Broman (1992)											4±		
Csapo et al. (2010)							5−					5−	
Kellis and Baltzopoulos (1997)											4±		
Shaffer et al. (2000)												5−	
Zakas et al. (2006)											4−		
Dudley et al. (1990)											4−		
Fiebert et al. (1996)						4+							
Cramer et al. (2007b)											4−		
Bazett-Jones et al. (2017)			1−	2−	3−								
Pinniger and Cresswell (2007)		5											
Blazevich et al. (2014)		5					5−						
Blazevich et al. (2012)		5											
Freire et al. (2017)		5					5−						
Konrad and Tilp (2014)		5											
Tourny-Chollet and Leroy (2002)											4±		
McHugh and Hogan (2004)						4−							
Cerrah et al. (2011)											4±		
Raiteri et al. (2023)							5+						
Kellis (2001)											4+		
Fouré et al. (2013)													
Hirata et al. (2017)		5											
Sacchetti et al. (2013)											4−		
Arampatzis et al. (2006a)						4−	5−						
Kubo et al. (2002)		5											

(*continued on next page*)

Table A.1 (*continued*).

Study	Available dataset(s)																	
	Passive						Isometric						Isokinetic					
Amiridis et al. (2005)											5+							
O'Neill et al. (2019)																	5−	
Ichinose et al. (2000)																4−		
Forrester and Pain (2010)																4−		
Babault et al. (2003)										4−						4−		
Clark and Franz (2019)					5													
Melo et al. (2016)																4±		
Hauraix et al. (2015)																	5−	
Tsaopoulos et al. (2011)										4−								
Kubo et al. (2006b)										4−								
Hirata et al. (2016)					5													
Vinti et al. (2013)											5±							
Kato et al. (2010)					5													
Noorkõiv et al. (2015)																4−		
Oliveira and Gonçalves (2009)										4±								
Kim (1998)										4±								
Nisell et al. (1989)																4−		
Locicero (1991)																4−		
Crotty et al. (2023)											5−							
Aagaard et al. (1997)																4±		
Morse et al. (2008)					5													
Barber et al. (2011)					5													
Karamanidis and Arampatzis (2005)										4−	5−							
Ando et al. (2018)																4−		
Chino et al. (2009)																	5−	
Perhonen et al. (1992)										4±								
Moltubakk et al. (2021)																	5−	
Silder et al. (2007)	1			4	5													
Kaminski and Dover (2001)																		6±
Moseley et al. (2001)					5													
Kitai and Sale (1989)											5−							
Jiroumaru et al. (2014)							1+											
Becker and Awiszus (2001)										4−								
Tourny-Chollet et al. (2000)																4±		
Chung et al. (2004)					5													
Milanezi et al. (2015)																		6±
Palmer et al. (2015)	1																	
Stotz et al. (2022)													1±	2±		4±	5±	
Savage et al. (2015)					5						5−							
Westing et al. (1988)										4−						4−		
Andrade et al. (2015)				4														
Tankevicius et al. (2013)												6±						
Cramer et al. (2007a)																4−		
Miyamoto and Oda (2003)											5−							
Funato (1994)													1±			4±	5±	
Thonnard et al. (1996)						6												
Labarque et al. (2002)																4±		
van Schaik et al. (1994)											5+							
Goharpey et al. (2007)																		6±
Schmitt et al. (2005)																	5±	
Shi et al. (2021)					5						5−							
Gonçalves et al. (2017)																	5±	
Hartsell (1994)																		6±
Toft et al. (1989)					5													
Gray and Chandler (1989)																4−		
Boling et al. (2009)													1−	2−	3−			
Hagen et al. (2015)												6±						
Le Sant et al. (2017)					5													
Ranisavljev et al. (2014)													1±			4±	5±	
Namazi et al. (2019)														2±		4±	5±	6±
Pelletier and Hicks (2010)											5±							
Aydoğ et al. (2004)																		
Svantesson et al. (1994)																	5−	
Sole et al. (2007)																4±		
Handel et al. (1997)																4±		
Salsich et al. (2000)					5													
McHugh and Tetro (2003)										4−								
Fugl-Meyer et al. (1980)																	5−	
Nagy et al. (2021)																		6±
Muraoka et al. (2002)					5													
Andrade et al. (2012)																4±		
Maganaris et al. (1998)											5−							
Olmo et al. (2009)																	5±	
Kindel and Challis (2018)							1−											

(*continued on next page*)

Table A.1 (*continued*).

Study	Available dataset(s)															
	Passive					Isometric					Isokinetic					
Kong (2023)															5±	
Lanza et al. (2003)									4−	5+						
Lacerte et al. (1992)														4−		
Yokozawa et al. (2019)											1−			4−	5−	
Aramaki et al. (2016)							2−									
Gajdosik et al. (1999)					5											
Chesworth and Vandervoort (1989)					5											
Folland and Morris (2008)									4−					4−		
Hornsby et al. (1987)										5−						
Levene et al. (1991)														4±		
Taylor et al. (1991)														4−		
Miyamoto et al. (2017)	1			4												
Kluka et al. (2016)										5−						
Connelly and Vandervoort (2000)															5+	
Kato et al. (2021)						1±										
Webber and Porter (2010)															5±	
Novak and Brouwer (2012)														4−	5−	
Costa et al. (2009)														4±		
Morris et al. (2021)									4±							
Al-Uzri et al. (2017)															5−	
Kellis (2019)									4±							
Porter et al. (1997)															5±	
Kim et al. (2010)											1±			4±	5±	
T'Jonck et al. (1997)															5±	
Kazazović et al. (2010)														4±		
Maffiuletti et al. (2007)									4−					4−		
Ueno et al. (2018)					5											
Pavol et al. (2002)											1±			4±	5±	
Bazett-Jones and Squier (2020)						1−	2−	3±								
Ewertowska et al. (2020)														4±		
Silva et al. (2015)														4±		6±
Vassis et al. (2020)														4−		
Wang et al. (2021)					5											
Hartmann et al. (2009)														4±		
Hamilton et al. (2008)														4±		
Horstmann et al. (2001)														4±	5±	
Lemaire et al. (2015)											1±					
Konrad et al. (2015)					5											
Fugl-Meyer et al. (1982)															5−	
Halbertsma et al. (1999)	1															
Pinniger et al. (2000)															5−	
Cudicio et al. (2022)										5+						
Vandervoort et al. (1990)														4±		
Klass et al. (2004)										5−						
Herda et al. (2008)									4+							
Dias et al. (2017)										5−						
Marshall et al. (2015)														4+		
Hiemstra et al. (2007)														4±		
Morse et al. (2005)										5−						
Weir et al. (1996b)									4−							
Hopkins et al. (1993)														4±		
Ferris and Hawkins (2020)					5					5−						
Geboers et al. (2000)										5+						
Valamatos et al. (2018)									4−							
Cramer et al. (2006)														4−		
Trezise and Blazevich (2019)														4−		
Sleivert and Wenger (1994)														4−	5−	
Henriksen et al. (2011)														4±		
Thomeé et al. (1995)																
Kim et al. (2016)														4±		
Lee et al. (2010)										5+						
Abdel-aziem and Mohammad (2012)															5−	
Reichard et al. (2005)														4±		
Chen et al. (2010)										5−						
Konrad et al. (2017)					5											
Westing and Seger (1989)														4±		
Baltzopoulos (1995)														4−		
Cheng et al. (2010)										5+						
Batista et al. (2009)														4±		
Tafazzoli and Lamontagne (1996)	1															
de Ruiter et al. (2004)									4−							
Narici et al. (1996)									4−							

(*continued on next page*)

Table A.1 (*continued*).

Study	Available dataset(s)								
	Passive			Isometric			Isokinetic		
Chiu et al. (2022)						5−			
Maffiuletti et al. (2002)						5±			5±
Tilp et al. (2011)						5+			
Meijer et al. (1998)					4−				
Fugl-Meyer et al. (1979)						5−			5−
Dalton et al. (2013)						5−			
Fillyaw et al. (1986)								4±	
Barber et al. (2012)			5			5−			
Carvalho et al. (2010)								4±	
Martin et al. (1994)						5−			5−
Nordez et al. (2008)		4							
Riener and Edrich (1999)	1	4	5						
Ayala et al. (2013)								4±	
Alt et al. (2019)								4+	

References

Aagaard, P., Simonsen, E.B., Andersen, J.L., Magnusson, S.P., Bojsen-Møller, F., Dyhre-Poulsen, P., 2000. Antagonist muscle coactivation during isokinetic knee extension. Scand. J. Med. Sci. Sports 10 (2), 58–67. http://dx.doi.org/10.1034/j.1600-0838.2000.010002058.x.

Aagaard, P., Simonsen, E., Beyer, N., Larsson, B., Magnusson, P., Kjaer, M., 1997. Isokinetic muscle strength and capacity for muscular knee joint stabilization in elite sailors. Int. J. Sports Med. 18 (07), 521–525. http://dx.doi.org/10.1055/s-2007-972675.

Abdel-aziem, A.A., Mohammad, W.S., 2012. Plantar-flexor static stretch training effect on eccentric and concentric peak torque–A comparative study of trained versus untrained subjects. J. Hum. Kinet. 34 (1), 49–58. http://dx.doi.org/10.2478/v10078-012-0063-z.

Abellaneda, S., Guissard, N., Duchateau, J., 2009. The relative lengthening of the myotendinous structures in the medial gastrocnemius during passive stretching differs among individuals. J. Appl. Physiol. 106 (1), 169–177. http://dx.doi.org/10.1152/japplphysiol.90577.2008.

Al-Uzri, M., O'Neill, S., Watson, P., Kelly, C., 2017. Reliability of isokinetic dynamometry of the plantarflexors in knee flexion and extension. Physiother. Pr. Res. 38 (1), 49–57. http://dx.doi.org/10.3233/PPR-160084.

Alahmri, F., Alsaadi, S., Ahsan, M., Almousa, S., 2022. The effect of isokinetic hip muscle strength on normal medial longitudinal arch feet and pes planus. J. Med. Life 15 (9), 1164–1169. http://dx.doi.org/10.25122/jml-2021-0319.

Alangari, A.S., Al-Hazzaa, H.M., 2004. Normal isometric and isokinetic peak torques of hamstring and quadriceps muscles in young adult Saudi males. Neurosci. (Riyadh, Saudi Arabia) 9 (3), 165–170.

Alt, T., Etzel, J.P., Knicker, A.J., Strüder, H.K., 2019. The effects of fixation and contraction mode on prone isokinetic knee flexor tests. Isokinet. Exerc. Sci. 27 (2), 143–151. http://dx.doi.org/10.3233/IES-192117.

Alt, T., Knicker, A.J., Strüder, H.K., 2014. Factors influencing the reproducibility of isokinetic knee flexion and extension test findings. Isokinet. Exerc. Sci. 22 (4), 333–342. http://dx.doi.org/10.3233/IES-140555.

Alt, T., Nolte, K., Horn, D., Modenbach, D., Jaitner, T., Knicker, A.J., 2024. Improving the ecological validity of isokinetic knee tests at different hip angles: Reciprocal concentric–eccentric movements as a suitable alternative for discrete tests. Res. Sport. Med. 32 (6), 885–901. http://dx.doi.org/10.1080/15438627.2023.2289036.

Alt, T., Nolte, K., Horn, D., Modenbach, D., Knicker, A.J., Jaitner, T., 2023. Analyses of isokinetic thigh muscle strength: Camera-based assessment alters the magnitude, but not the message. Res. Q. Exerc. Sport 94 (3), 783–792. http://dx.doi.org/10.1080/02701367.2022.2053648.

Alt, T., Richert, M., Schwarz, Y.M., Knicker, A.J., Strüder, H.K., 2016. Minimal fixation suffices for supine isokinetic knee extension: A kinetic and 3D kinematic analysis. Isokinet. Exerc. Sci. 24 (4), 301–311. http://dx.doi.org/10.3233/IES-160630.

Amiridis, I., Arabatzi, F., Violaris, P., Stavropoulos, E., Hatzitaki, V., 2005. Static balance improvement in elderly after dorsiflexors electrostimulation training. Eur. J. Appl. Physiol. 94 (4), 424–433. http://dx.doi.org/10.1007/s00421-005-1326-3.

Anderson, D.E., Madigan, M.L., Nussbaum, M.A., 2007. Maximum voluntary joint torque as a function of joint angle and angular velocity: Model development and application to the lower limb. J. Biomech. 40 (14), 3105–3113. http://dx.doi.org/10.1016/j.jbiomech.2007.03.022.

Anderson, F.C., Pandy, M.G., 1999. A dynamic optimization solution for vertical jumping in three dimensions. Comput. Methods Biomech. Biomed. Eng. 2 (3), 201–231. http://dx.doi.org/10.1080/10255849908907988.

Ando, R., Nosaka, K., Tomita, A., Watanabe, K., Blazevich, A.J., Akima, H., 2018. Vastus intermedius vs vastus lateralis fascicle behaviors during maximal concentric and eccentric contractions. Scand. J. Med. Sci. Sports 28 (3), 1018–1026. http://dx.doi.org/10.1111/sms.13022.

Andrade, M.D.S., De Lira, C.A.B., Koffes, F.D.C., Mascarin, N.C., Benedito-Silva, A.A., Da Silva, A.C., 2012. Isokinetic hamstrings-to-quadriceps peak torque ratio: The influence of sport modality, gender, and angular velocity. J. Sports Sci. 30 (6), 547–553. http://dx.doi.org/10.1080/02640414.2011.644249.

Andrade, R.J., Freitas, S.R., Vaz, J.R., Bruno, P.M., Pezarat-Correia, P., 2015. Provocative mechanical tests of the peripheral nervous system affect the joint torque–angle during passive knee motion. Scand. J. Med. Sci. Sports 25 (3), 338–345. http://dx.doi.org/10.1111/sms.12250.

Andrade, R.J., Lacourpaille, L., Freitas, S.R., McNair, P.J., Nordez, A., 2016. Effects of hip and head position on ankle range of motion, ankle passive torque, and passive gastrocnemius tension. Scand. J. Med. Sci. Sports 26 (1), 41–47. http://dx.doi.org/10.1111/sms.12406.

Aramaki, H., Katoh, M., Hiiragi, Y., Kawasaki, T., Kurihara, T., Ohmi, Y., 2016. Validity and reliability of isometric muscle strength measurements of hip abduction and abduction with external hip rotation in a bent-hip position using a handheld dynamometer with a belt. J. Phys. Ther. Sci. 28 (7), 2123–2127. http://dx.doi.org/10.1589/jpts.28.2123.

Arampatzis, A., De Monte, G., Karamanidis, K., Morey-Klapsing, G., Stafilidis, S., Brüggemann, G.-P., 2006a. Influence of the muscle–tendon unit's mechanical and morphological properties on running economy. J. Exp. Biol. 209 (17), 3345–3357. http://dx.doi.org/10.1242/jeb.02340.

Arampatzis, A., De Monte, G., Morey-Klapsing, G., 2007. Effect of contraction form and contraction velocity on the differences between resultant and measured ankle joint moments. J. Biomech. 40 (7), 1622–1628. http://dx.doi.org/10.1016/j.jbiomech.2006.06.011.

Arampatzis, A., Karamanidis, K., Stafilidis, S., Morey-Klapsing, G., De Monte, G., Brüggemann, G.-P., 2006b. Effect of different ankle- and knee-joint positions on gastrocnemius medialis fascicle length and EMG activity during isometric plantar flexion. J. Biomech. 39 (10), 1891–1902. http://dx.doi.org/10.1016/j.jbiomech.2005.05.010.

Arnold, B., Perrin, D., Kahler, D., Gansneder, B., Gieck, J., 1996. Effects of cutaneous and joint receptors on the in vivo quadriceps femoris torque–velocity relationship. Isokinet. Exerc. Sci. 5 (3–4), 149–155. http://dx.doi.org/10.3233/IES-1996-53-408.

Arokoski, M.H., Arokoski, J.P.A., Haara, M., Kankaanpää, M., Vesterinen, M., Niemitukia, L.H., Helminen, H.J., 2002. Hip muscle strength and muscle cross sectional area in men with and without hip osteoarthritis. J. Rheumatol. 29 (10), 2185–2195.

Atabek, H.Ç., Sönmez, G.A., Yılmaz, İ., 2009. The relationship between isokinetic strength of knee extensors/flexors, jumping and anaerobic performance. Isokinet. Exerc. Sci. 17 (2), 79–83. http://dx.doi.org/10.3233/IES-2009-0337.

Ateş, F., Davies, B.L., Chopra, S., Coleman-Wood, K., Litchy, W.J., Kaufman, K.R., 2018. Intramuscular pressure of tibialis anterior reflects ankle torque but does not follow joint angle–torque relationship. Front. Physiol. 9, 22. http://dx.doi.org/10.3389/fphys.2018.00022.

Ayala, F., De Ste Croix, M., Sainz De Baranda, P., Santonja, F., 2013. Absolute reliability of isokinetic knee flexion and extension measurements adopting a prone position. Clin. Physiol. Funct. Imaging 33 (1), 45–54. http://dx.doi.org/10.1111/j.1475-097X.2012.01162.x.

Aydoğ, E., Aydoğ, S.T., Çakci, A., Doral, M.N., 2004. Reliability of isokinetic ankle inversion- and eversion-strength measurement in neutral foot position, using the Biodex dynamometer. Knee Surg. Sport. Traumatol. Arthrosc. 12 (5), 478–481. http://dx.doi.org/10.1007/s00167-004-0530-8.

Babault, N., Pousson, M., Michaut, A., Van Hoecke, J., 2003. Effect of quadriceps femoris muscle length on neural activation during isometric and concentric contractions. J. Appl. Physiol. 94 (3), 983–990. http://dx.doi.org/10.1152/japplphysiol.00717.2002.

Baltzopoulos, V., 1995. Muscular and tibiofemoral joint forces during isokinetic concentric knee extension. Clin. Biomech. 10 (4), 208–214. http://dx.doi.org/10.1016/0268-0033(95)91399-Y.

Baltzopoulos, V., 2007. Isokinetic dynamometry. In: Biomechanical Evaluation of Movement in Sport and Exercise: the British Association of Sport and Exercise Sciences Guide. Routledge, pp. 103–128. http://dx.doi.org/10.4324/9780203935750.

Barber, L.A., Barrett, R.S., Gillett, J.G., Cresswell, A.G., Lichtwark, G.A., 2013. Neuromechanical properties of the triceps surae in young and older adults. Exp. Geront. 48 (11), 1147–1155. http://dx.doi.org/10.1016/j.exger.2013.07.007.

Barber, L., Barrett, R., Lichtwark, G., 2011. Passive muscle mechanical properties of the medial gastrocnemius in young adults with spastic cerebral palsy. J. Biomech. 44 (13), 2496–2500. http://dx.doi.org/10.1016/j.jbiomech.2011.06.008.

Barber, L., Barrett, R., Lichtwark, G., 2012. Medial gastrocnemius muscle fascicle active torque–length and Achilles tendon properties in young adults with spastic cerebral palsy. J. Biomech. 45 (15), 2526–2530. http://dx.doi.org/10.1016/j.jbiomech.2012.07.018.

Barr, A.E., Duncan, P.W., 1988. Influence of position on knee flexor peak torque. J. Orthop. Sport. Phys. Ther. 9 (8), 279–283. http://dx.doi.org/10.2519/jospt.1988.9.8.279.

Batista, L.H., Vilar, A.C., de Almeida Ferreira, J.J., Rebelatto, J.R., Salvini, T.F., 2009. Active stretching improves flexibility, joint torque, and functional mobility in older women. Am. J. Phys. Med. Rehabil. 88 (10), 815–822. http://dx.doi.org/10.1097/PHM.0b013e3181b72149.

Baxter, J.R., Piazza, S.J., 2014. Plantar flexor moment arm and muscle volume predict torque-generating capacity in young men. J. Appl. Physiol. 116 (5), 538–544. http://dx.doi.org/10.1152/japplphysiol.01140.2013.

Bazett-Jones, D.M., Squier, K., 2020. Measurement properties of hip strength measured by handheld dynamometry: Reliability and validity across the range of motion. Phys. Ther. Sport. 42, 100–106. http://dx.doi.org/10.1016/j.ptsp.2020.01.005.

Bazett-Jones, D.M., Tylinksi, T., Krstic, J., Stromquist, A., Sparks, J., 2017. Peak hip muscle torque measurements are influenced by sagittal plane hip position. Int. J. Sport. Phys. Ther. 12 (4), 535–542.

Beck, M., Krüger, A., Katthagen, C., Kohl, S., 2015. Osteotomy of the greater trochanter: Effect on gluteus medius function. Surg. Radiol. Anat. 37 (6), 599–607. http://dx.doi.org/10.1007/s00276-015-1466-z.

Becker, R., Awiszus, F., 2001. Physiological alterations of maximal voluntary quadriceps activation by changes of knee joint angle. Muscle Nerve 24 (5), 667–672. http://dx.doi.org/10.1002/mus.1053.

Beynnon, B.D., Renström, P.A., Alosa, D.M., Baumhauer, J.F., Vacek, P.M., 2001. Ankle ligament injury risk factors: A prospective study of college athletes. J. Orthop. Res. 19 (2), 213–220. http://dx.doi.org/10.1016/S0736-0266(00)90004-4.

Billot, M., Simoneau, E.M., Ballay, Y., Van Hoecke, J., Martin, A., 2011. How the ankle joint angle alters the antagonist and agonist torques during maximal efforts in dorsi- and plantar flexion. Scand. J. Med. Sci. Sports 21 (6), http://dx.doi.org/10.1111/j.1600-0838.2010.01278.x.

Blazevich, A.J., Cannavan, D., Waugh, C.M., Fath, F., Miller, S.C., Kay, A.D., 2012. Neuromuscular factors influencing the maximum stretch limit of the human plantar flexors. J. Appl. Physiol. 113 (9), 1446–1455. http://dx.doi.org/10.1152/japplphysiol.00882.2012.

Blazevich, A.J., Cannavan, D., Waugh, C.M., Miller, S.C., Thorlund, J.B., Aagaard, P., Kay, A.D., 2014. Range of motion, neuromechanical, and architectural adaptations to plantar flexor stretch training in humans. J. Appl. Physiol. 117 (5), 452–462. http://dx.doi.org/10.1152/japplphysiol.00204.2014.

Blazevich, A.J., Coleman, D.R., Horne, S., Cannavan, D., 2009. Anatomical predictors of maximum isometric and concentric knee extensor moment. Eur. J. Appl. Physiol. 105 (6), 869–878. http://dx.doi.org/10.1007/s00421-008-0972-7.

Bobbert, M.F., van Ingen Schenau, G.J., 1990. Isokinetic plantar flexion: Experimental results and model calculations. J. Biomech. 23 (2), 105–119. http://dx.doi.org/10.1016/0021-9290(90)90345-4.

Bohannon, R.W., Gajdosik, R.L., LeVeau, B.F., 1986. Isokinetic knee flexion and extension torque in the upright sitting and semireclined sitting positions. Phys. Ther. 66 (7), 1083–1086. http://dx.doi.org/10.1093/ptj/66.7.1083.

Boling, M.C., Padua, D.A., Alexander Creighton, R., 2009. Concentric and eccentric torque of the hip musculature in individuals with and without patellofemoral pain. J. Athl. Train. 44 (1), 7–13. http://dx.doi.org/10.4085/1062-6050-44.1.7.

Cahalan, T.D., Johnson, M.E., Liu, S., Chao, E.Y., 1989. Quantitative measurements of hip strength in different age groups. Clin. Orthop. Relat. Res. 246, 136–145.

Caldwell, G.E., Adams, III, W.B., Whetstone, M.R., 1993. Torque/velocity properties of human knee muscles: Peak and angle-specific estimates. Can. J. Appl. Physiol. 18 (3), 274–290. http://dx.doi.org/10.1139/h93-024.

Camargo, J., Ramanathan, A., Flanagan, W., Young, A., 2021. A comprehensive, open-source dataset of lower limb biomechanics in multiple conditions of stairs, ramps, and level-ground ambulation and transitions. J. Biomech. 119, 110320. http://dx.doi.org/10.1016/j.jbiomech.2021.110320.

Cammarata, M.L., Dhaher, Y.Y., 2008. The differential effects of gender, anthropometry, and prior hormonal state on frontal plane knee joint stiffness. Clin. Biomech. 23 (7), 937–945. http://dx.doi.org/10.1016/j.clinbiomech.2008.03.071.

Carvalho, J., Marques, E., Soares, J.M.C., Mota, J., 2010. Isokinetic strength benefits after 24 weeks of multicomponent exercise training and combined exercise training in older adults. Aging Clin. Exp. Res. 22 (1), 63–69. http://dx.doi.org/10.1007/BF03324817.

Cerrah, A.O., Gungor, E.O., Soylu, A.R., Ertan, H., Lees, A., Bayrak, C., 2011. Muscular activation patterns during the soccer in-step kick. Isokinet. Exerc. Sci. 19 (3), 181–190. http://dx.doi.org/10.3233/IES-2011-0414.

Chen, Z., Franklin, D.W., 2024. Muscle moment arm–joint angle relations in the hip, knee, and ankle: A visualization of datasets. http://dx.doi.org/10.1101/2024.06.22.600198, bioRxiv.

Chen, S., Wang, D., Zhang, Q., Shi, Y., Ding, H., Li, F., 2022. Relationship between isokinetic lower-limb joint strength, isometric time force characteristics, and leg-spring stiffness in recreational runners. Front. Physiol. 12, 797682. http://dx.doi.org/10.3389/fphys.2021.797682.

Chen, Y.-S., Zhou, S., Cartwright, C., Crowley, Z., Baglin, R., Wang, F., 2010. Test-retest reliability of the soleus H-reflex is affected by joint positions and muscle force levels. J. Electromyography Kinesiol. 20 (5), 980–987. http://dx.doi.org/10.1016/j.jelekin.2009.11.003.

Cheng, A.J., Davidson, A.W., Rice, C.L., 2010. The influence of muscle length on the fatigue-related reduction in joint range of motion of the human dorsiflexors. Eur. J. Appl. Physiol. 109 (3), 405–415. http://dx.doi.org/10.1007/s00421-010-1364-3.

Cheng, A.J., Rice, C.L., 2013. Factors contributing to the fatigue-related reduction in active dorsiflexion joint range of motion. Appl. Physiol. Nutr. Metab. 38 (5), 490–497. http://dx.doi.org/10.1139/apnm-2012-0357.

Chesworth, B.M., Vandervoort, A.A., 1989. Age and passive ankle stiffness in healthy women. Phys. Ther. 69 (3), 217–224. http://dx.doi.org/10.1093/ptj/69.3.217.

Chino, K., Mitsukawa, N., Kobayashi, K., Miyoshi, Y., Oda, T., Kanehisa, H., Fukunaga, T., Fukashiro, S., Kawakami, Y., 2009. The influence of fascicle behavior on the lack of velocity dependence in eccentric joint torque in humans: In vivo observation. J. Appl. Biomech. 25 (2), 111–118. http://dx.doi.org/10.1123/jab.25.2.111.

Chiu, L.Z., Dæhlin, T.E., Jean, L.M., Fielding, Z.A., 2022. Correcting for heel lift reduces ankle joint operating range for the ankle plantar flexor strength curve. J. Biomech. 134, 110998. http://dx.doi.org/10.1016/j.jbiomech.2022.110998.

Chung, S.G., van Rey, E., Bai, Z., Roth, E.J., Zhang, L.-Q., 2004. Biomechanic changes in passive properties of hemiplegic ankles with spastic hypertonia. Arch. Phys. Med. Rehabil. 85 (10), 1638–1646. http://dx.doi.org/10.1016/j.apmr.2003.11.041.

Claiborne, T.L., Armstrong, C.W., Gandhi, V., Pincivero, D.M., 2006. Relationship between hip and knee strength and knee valgus during a single leg squat. J. Appl. Biomech. 22 (1), 41–50. http://dx.doi.org/10.1123/jab.22.1.41.

Clark, W.H., Franz, J.R., 2019. Activation-dependent changes in soleus length–tension behavior augment ankle joint quasi-stiffness. J. Appl. Biomech. 35 (3), 182–189. http://dx.doi.org/10.1123/jab.2018-0297.

Colliander, E.B., Tesch, P.A., 1989. Bilateral eccentric and concentric torque of quadriceps and hamstring muscles in females and males. Eur. J. Appl. Physiol. 59 (3), 227–232. http://dx.doi.org/10.1007/BF02386192.

Cometti, G., Maffiuletti, N.A., Pousson, M., Chatard, J.-C., Maffulli, N., 2001. Isokinetic strength and anaerobic power of elite, subelite and amateur french soccer players. Int. J. Sports Med. 22 (1), 45–51. http://dx.doi.org/10.1055/s-2001-11331.

Connelly, D.M., Vandervoort, A.A., 2000. Effects of isokinetic strength training on concentric and eccentric torque development in the ankle dorsiflexors of older adults. J. Gerontol. Ser. A: Biol. Sci. Med. Sci. 55 (10), B465–B472. http://dx.doi.org/10.1093/gerona/55.10.B465.

Costa, P.B., Ryan, E.D., Herda, T.J., Defreitas, J.M., Beck, T.W., Cramer, J.T., 2009. Effects of static stretching on the hamstrings-to-quadriceps ratio and electromyographic amplitude in men. J. Sport. Med. Phys. Fit. 49 (4), 401–409.

Cramer, J.T., Beck, T.W., Housh, T.J., Massey, L.L., Marek, S.M., Danglemeier, S., Purkayastha, S., Culbertson, J.Y., Fitz, K.A., Egan, A.D., 2007a. Acute effects of static stretching on characteristics of the isokinetic angle–torque relationship, surface electromyography, and mechanomyography. J. Sports Sci. 25 (6), 687–698. http://dx.doi.org/10.1080/02640410600818416.

Cramer, J.T., Housh, T.J., Coburn, J.W., Beck, T.W., Johnson, G.O., 2006. Acute effects of static stretching on maximal eccentric torque production in women. J. Strength Cond. Res. 20 (2), 354–358. http://dx.doi.org/10.1519/R-18105.1.

Cramer, J.T., Housh, T.J., Johnson, G.O., Weir, J.P., Beck, T.W., Coburn, J.W., 2007b. An acute bout of static stretching does not affect maximal eccentric isokinetic peak torque, the joint angle at peak torque, mean power, electromyography, or mechanomyography. J. Orthop. Sport. Phys. Ther. 37 (3), 130–139. http://dx.doi.org/10.2519/jospt.2007.2389.

Cresswell, A., Löscher, W., Thorstensson, A., 1995. Influence of gastrocnemius muscle length on triceps surae torque development and electromyographic activity in man. Exp. Brain Res. 105 (2), 283–290. http://dx.doi.org/10.1007/BF00240964.

Crotty, E.D., Furlong, L.-A.M., Harrison, A.J., 2023. Reliability of mechanical properties of the plantar flexor muscle tendon unit with consideration to joint angle and sex. PLoS One 18 (6), e0287431. http://dx.doi.org/10.1371/journal.pone.0287431.

Csapo, R., Maganaris, C.N., Seynnes, O.R., Narici, M.V., 2010. On muscle, tendon and high heels. J. Exp. Biol. 213 (15), 2582–2588. http://dx.doi.org/10.1242/jeb.044271.

Cudicio, A., Martinez-Valdes, E., Cogliati, M., Orizio, C., Negro, F., 2022. The force-generation capacity of the tibialis anterior muscle at different muscle–tendon lengths depends on its motor unit contractile properties. Eur. J. Appl. Physiol. 122 (2), 317–330. http://dx.doi.org/10.1007/s00421-021-04829-8.

Dalton, B.H., Power, G.A., Allen, M.D., Vandervoort, A.A., Rice, C.L., 2013. The genu effect on plantar flexor power. Eur. J. Appl. Physiol. 113 (6), 1431–1439. http://dx.doi.org/10.1007/s00421-012-2560-0.

Daneshjoo, A., Rahnama, N., Mokhtar, A.H., Yusof, A., 2013. Bilateral and unilateral asymmetries of isokinetic strength and flexibility in male young professional soccer players. J. Hum. Kinet. 36 (1), 45–53. http://dx.doi.org/10.2478/hukin-2013-0005.

Danneskiold-Samsøe, B., Bartels, E.M., Bülow, P.M., Lund, H., Stockmarr, A., Holm, C.C., Wätjen, I., Appleyard, M., Bliddal, H., 2009. Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender. Acta Physiol. 197 (s673), 1–68. http://dx.doi.org/10.1111/j.1748-1716.2009.02022.x.

De Luca, C.J., 1997. The use of surface electromyography in biomechanics. J. Appl. Biomech. 13 (2), 135–163. http://dx.doi.org/10.1123/jab.13.2.135.

de Ruiter, C.J., Kooistra, R.D., Paalman, M.I., de Haan, A., 2004. Initial phase of maximal voluntary and electrically stimulated knee extension torque development at different knee angles. J. Appl. Physiol. 97 (5), 1693–1701. http://dx.doi.org/10.1152/japplphysiol.00230.2004.

Delp, S.L., Anderson, F.C., Arnold, A.S., Loan, P., Habib, A., John, C.T., Guendelman, E., Thelen, D.G., 2007. OpenSim: Open-source software to create and analyze dynamic simulations of movement. IEEE Trans. Biomed. Eng. 54 (11), 1940–1950. http://dx.doi.org/10.1109/TBME.2007.901024.

Delp, S., Loan, J., Hoy, M., Zajac, F., Topp, E., Rosen, J., 1990. An interactive graphics-based model of the lower extremity to study orthopaedic surgical procedures. IEEE Trans. Biomed. Eng. 37 (8), 757–767. http://dx.doi.org/10.1109/10.102791.

Derrick, T.R., van den Bogert, A.J., Cereatti, A., Dumas, R., Fantozzi, S., Leardini, A., 2020. ISB recommendations on the reporting of intersegmental forces and moments during human motion analysis. J. Biomech. 99, 109533. http://dx.doi.org/10.1016/j.jbiomech.2019.109533.

di Vico, R., Ardigò, L.P., Salernitano, G., Chamari, K., Padulo, J., 2013. The acute effect of the tongue position in the mouth on knee isokinetic test performance: A highly surprising pilot study. Muscles Ligaments Tendons J. 3 (4), 318–323.

Dias, C.P., Freire, B., Goulart, N.B.A., Onzi, E.S., Becker, J., Gomes, I., Arampatzis, A., Vaz, M.A., 2017. Muscle architecture and torque production in stroke survivors: An observational study. Top. Stroke Rehabil. 24 (3), 206–213. http://dx.doi.org/10.1080/10749357.2016.1210873.

Dirnberger, J., Wiesinger, H.-P., Kösters, A., Müller, E., 2012. Reproducibility for isometric and isokinetic maximum knee flexion and extension measurements using the IsoMed 2000-dynamometer. Isokinet. Exerc. Sci. 20 (3), 149–153. http://dx.doi.org/10.3233/IES-2012-0451.

Donatelli, R., Catlin, P.A., Backer, G.S., Drane, D.L., Slater, S.M., 1991. Isokinetic hip abductor to adductor torque ratio in normals. Isokinet. Exerc. Sci. 1 (2), 103–111. http://dx.doi.org/10.3233/IES-1991-1209.

Drazan, J.F., Hullfish, T.J., Baxter, J.R., 2019. Muscle structure governs joint function: Linking natural variation in medial gastrocnemius structure with isokinetic plantar flexor function. Biol. Open 8 (12), bio.048520. http://dx.doi.org/10.1242/bio.048520.

Dudley, G.A., Harris, R.T., Duvoisin, M.R., Hather, B.M., Buchanan, P., 1990. Effect of voluntary vs. artificial activation on the relationship of muscle torque to speed. J. Appl. Physiol. 69 (6), 2215–2221. http://dx.doi.org/10.1152/jappl.1990.69.6.2215.

Ekdahl, C., Broman, G., 1992. Muscle strength, endurance, and aerobic capacity in rheumatoid arthritis: A comparative study with healthy subjects. Ann. Rheum. Dis. 51 (1), 35–40. http://dx.doi.org/10.1136/ard.51.1.35.

Eng, C.M., Arnold, A.S., Lieberman, D.E., Biewener, A.A., 2015. The capacity of the human iliotibial band to store elastic energy during running. J. Biomech. 48 (12), 3341–3348. http://dx.doi.org/10.1016/j.jbiomech.2015.06.017.

Ewertowska, P., Trzaskoma, Z., Sitarski, D., Gromuł, B., Haponiuk, I., Czaprowski, D., 2020. Muscle strength, muscle power and body composition in college-aged young women and men with generalized joint hypermobility. PLoS One 15 (7), e0236266. http://dx.doi.org/10.1371/journal.pone.0236266.

Ferri, A., Scaglioni, G., Pousson, M., Capodaglio, P., Van Hoecke, J., Narici, M.V., 2003. Strength and power changes of the human plantar flexors and knee extensors in response to resistance training in old age. Acta Physiol. Scand. 177 (1), 69–78. http://dx.doi.org/10.1046/j.1365-201X.2003.01050.x.

Ferris, R.M., Hawkins, D.A., 2020. Gastrocnemius and soleus muscle contributions to ankle plantar flexion torque as a function of ankle and knee angle. Sport. Inj. Med. 4 (1), http://dx.doi.org/10.29011/2576-9596.100063.

Fiebert, I.M., Pahl, C.H., Applegate, E.B., Spielholz, N.I., Beernik, K., 1996. Medial–lateral hamstring electromyographic activity during maximum isometric knee flexion at different angles. Isokinet. Exerc. Sci. 6 (2), 157–162. http://dx.doi.org/10.3233/IES-1996-6213.

Fillyaw, M., Bevins, T., Fernandez, L., 1986. Importance of correcting isokinetic peak torque for the effect of gravity when calculating knee flexor to extensor muscle ratios. Phys. Ther. 66 (1), 23–29. http://dx.doi.org/10.1093/ptj/66.1.23.

Finni, T., Ikegaw, S., Lepola, V., Komi, P., 2001. In vivo behavior of vastus lateralis muscle during dynamic performances. Eur. J. Sport. Sci. 1 (1), 1–13. http://dx.doi.org/10.1080/17461390100071101.

Fletcher, J.R., MacIntosh, B.R., 2018. Estimates of Achilles tendon moment arm length at different ankle joint angles: Effect of passive moment. J. Appl. Biomech. 34 (3), 220–225. http://dx.doi.org/10.1123/jab.2016-0263.

Folland, J., Morris, B., 2008. Variable-cam resistance training machines: Do they match the angle–torque relationship in humans? J. Sports Sci. 26 (2), 163–169. http://dx.doi.org/10.1080/02640410701370663.

Forrester, S.E., Pain, M.T., 2010. A combined muscle model and wavelet approach to interpreting the surface EMG signals from maximal dynamic knee extensions. J. Appl. Biomech. 26 (1), 62–72. http://dx.doi.org/10.1123/jab.26.1.62.

Fouré, A., Nordez, A., Cornu, C., 2013. Effects of eccentric training on mechanical properties of the plantar flexor muscle–tendon complex. J. Appl. Physiol. 114 (5), 523–537. http://dx.doi.org/10.1152/japplphysiol.01313.2011.

Fouré, A., Nordez, A., Guette, M., Cornu, C., 2009. Effects of plyometric training on passive stiffness of gastrocnemii and the musculo–articular complex of the ankle joint. Scand. J. Med. Sci. Sports 19 (6), 811–818. http://dx.doi.org/10.1111/j.1600-0838.2008.00853.x.

Fowles, J.R., Sale, D.G., MacDougall, J.D., 2000. Reduced strength after passive stretch of the human plantarflexors. J. Appl. Physiol. 89 (3), 1179–1188. http://dx.doi.org/10.1152/jappl.2000.89.3.1179.

Franklin, D.W., Osu, R., Burdet, E., Kawato, M., Milner, T.E., 2003. Adaptation to stable and unstable dynamics achieved by combined impedance control and inverse dynamics model. J. Neurophysiol. 90 (5), 3270–3282. http://dx.doi.org/10.1152/jn.01112.2002.

Freire, B., Dias, C.P., Goulart, N.B.A., de Castro, C.D., Becker, J., Gomes, I., Vaz, M.A., 2017. Achilles tendon morphology, plantar flexors torque and passive ankle stiffness in spastic hemiparetic stroke survivors. Clin. Biomech. 41, 72–76. http://dx.doi.org/10.1016/j.clinbiomech.2016.12.004.

Freitas, S.R., Vaz, J.R., Bruno, P.M., Valamatos, M.J., Mil-Homens, P., 2013. Comparison of different passive knee extension torque–angle assessments. Physiol. Meas. 34 (11), 1483–1498. http://dx.doi.org/10.1088/0967-3334/34/11/1483.

Frey-Law, L.A., Laake, A., Avin, K.G., Heitsman, J., Marler, T., Abdel-Malek, K., 2012. Knee and elbow 3D strength surfaces: Peak torque–angle–velocity relationships. J. Appl. Biomech. 28 (6), 726–737. http://dx.doi.org/10.1123/jab.28.6.726.

Fugl-Meyer, A.R., 1981. Maximum isokinetic ankle plantar and dorsal flexion torques in trained subjects. Eur. J. Appl. Physiol. 47 (4), 393–404. http://dx.doi.org/10.1007/BF02332967.

Fugl-Meyer, A.R., Gustafsson, L., Burstedt, Y., 1980. Isokinetic and static plantar flexion characteristics. Eur. J. Appl. Physiol. 45 (2–3), 221–234. http://dx.doi.org/10.1007/BF00421330.

Fugl-Meyer, A.R., Mild, K.H., Hörnsten, J., 1982. Output of skeletal muscle contractions: A study of isokinetic plantar flexion in athletes. Acta Physiol. Scand. 115 (2), 193–199. http://dx.doi.org/10.1111/j.1748-1716.1982.tb07065.x.

Fugl-Meyer, A.R., Sjöström, M., Wählby, L., 1979. Human plantar flexion strength and structure. Acta Physiol. Scand. 107 (1), 47–56. http://dx.doi.org/10.1111/j.1748-1716.1979.tb06441.x.

Fukuchi, R.K., Fukuchi, C.A., Duarte, M., 2017. A public dataset of running biomechanics and the effects of running speed on lower extremity kinematics and kinetics. PeerJ 5, e3298. http://dx.doi.org/10.7717/peerj.3298.

Funato, K., 1994. Torque–velocity patterns of hip, knee and ankle flexors and extensors during concentric and eccentric actions. 東京大学教養学部体育学紀要 [Sport. Sci. Bull. Coll. Arts Sci. Univ. Tokyo] 28, 7–14.

Gajdosik, R., 2002. Relationship between passive properties of the calf muscles and plantarflexion concentric isokinetic torque characteristics. Eur. J. Appl. Physiol. 87 (3), 220–227. http://dx.doi.org/10.1007/s00421-002-0624-2.

Gajdosik, R.L., Vander Linden, D.W., Williams, A.K., 1999. Influence of age on length and passive elastic stiffness characteristics of the calf muscle–tendon unit of women. Phys. Ther. 79 (9), 827–838. http://dx.doi.org/10.1093/ptj/79.9.827.

Gallinger, T.L., Fletcher, J.R., MacIntosh, B.R., 2020. Mechanisms of reduced plantarflexor function in cerebral palsy: Smaller triceps surae moment arm and reduced muscle force. J. Biomech. 110, 109959. http://dx.doi.org/10.1016/j.jbiomech.2020.109959.

Geboers, J.F., van Tuijl, J.H., Seelen, H.A., Drost, M.R., 2000. Effect of immobilization on ankle dorsiflexion strength. Scand. J. Rehabil. Med. 32 (2), 66–71. http://dx.doi.org/10.1080/003655000750045578.

Gerrits, K., Gommans, I., van Engelen, B., de Haan, A., 2003. Quadriceps weakness in a family with nemaline myopathy: Influence of knee angle. Clin. Sci. 105 (5), 585–589. http://dx.doi.org/10.1042/CS20030159.

Gleeson, N.P., Mercer, T.H., 1996. The utility of isokinetic dynamometry in the assessment of human muscle function. Sports Med. 21, 18–34. http://dx.doi.org/10.1152/ajpcell.00046.2016.

Goharpey, S., Sadeghi, M., Maroufi, N., Shaterzadeh, M., 2007. Comparison of invertor and evertor muscle strength in patients with chronic functional ankle instability. J. Med. Sci. 7 (4), 674–677. http://dx.doi.org/10.3923/jms.2007.674.677.

Gollapudi, S.K., Lin, D.C., 2009. Experimental determination of sarcomere force–length relationship in type-I human skeletal muscle fibers. J. Biomech. 42 (13), 2011–2016. http://dx.doi.org/10.1016/j.jbiomech.2009.06.013.

Gonçalves, G.H., Sendín, F.A., da Silva Serrão, P.R.M., Selistre, L.F.A., Petrella, M., Carvalho, C., Mattiello, S.M., 2017. Ankle strength impairments associated with knee osteoarthritis. Clin. Biomech. 46, 33–39. http://dx.doi.org/10.1016/j.clinbiomech.2017.05.002.

Gravel, D., Richards, C.L., Filion, M., 1990. Angle dependency in strength measurements of the ankle plantar flexors. Eur. J. Appl. Physiol. 61 (3–4), 182–187. http://dx.doi.org/10.1007/BF00357596.

Gray, J.C., Chandler, J.M., 1989. Percent decline in peak torque production during repeated concentric and eccentric contractions of the quadriceps femoris muscle. J. Orthop. Sport. Phys. Ther. 10 (8), 309–314. http://dx.doi.org/10.2519/jospt.1989.10.8.309.

Guilhem, G., Cornu, C., Guével, A., 2011. Muscle architecture and EMG activity changes during isotonic and isokinetic eccentric exercises. Eur. J. Appl. Physiol. 111 (11), 2723–2733. http://dx.doi.org/10.1007/s00421-011-1894-3.

Gupta, A., Fernihough, B., Bailey, G., Bombeck, P., Clarke, A., Hopper, D., 2004. An evaluation of differences in hip external rotation strength and range of motion between female dancers and non-dancers. Br. J. Sports Med. 38 (6), 778–783. http://dx.doi.org/10.1136/bjsm.2003.010827.

Hagen, M., Lemke, M., Kutsch, H.-P., Lahner, M., 2015. Development of a functional anatomical subtalar pronator and supinator strength training machine. Technol. Health Care 23 (5), 627–635. http://dx.doi.org/10.3233/THC-151004.

Hahn, M.E., 2007. Feasibility of estimating isokinetic knee torque using a neural network model. J. Biomech. 40 (5), 1107–1114. http://dx.doi.org/10.1016/j.jbiomech.2006.04.014.

Hahn, D., Herzog, W., Schwirtz, A., 2014. Interdependence of torque, joint angle, angular velocity and muscle action during human multi-joint leg extension. Eur. J. Appl. Physiol. 114 (8), 1691–1702. http://dx.doi.org/10.1007/s00421-014-2899-5.

Hahn, D., Olvermann, M., Richtberg, J., Seiberl, W., Schwirtz, A., 2011. Knee and ankle joint torque–angle relationships of multi-joint leg extension. J. Biomech. 44 (11), 2059–2065. http://dx.doi.org/10.1016/j.jbiomech.2011.05.011.

Halbertsma, J.P., Mulder, I., Göeken, L.N., Eisma, W.H., 1999. Repeated passive stretching: Acute effect on the passive muscle moment and extensibility of short hamstrings. Arch. Phys. Med. Rehabil. 80 (4), 407–414. http://dx.doi.org/10.1016/S0003-9993(99)90277-0.

Hald, R.D., Bottjen, E.J., 1987. Effect of visual feedback on maximal and submaximal isokinetic test measurements of normal quadriceps and hamstrings. J. Orthop. Sport. Phys. Ther. 9 (2), 86–93. http://dx.doi.org/10.2519/jospt.1987.9.2.86.

Hamilton, R.T., Shultz, S.J., Schmitz, R.J., Perrin, D.H., 2008. Triple-hop distance as a valid predictor of lower limb strength and power. J. Athl. Train. 43 (2), 144–151. http://dx.doi.org/10.4085/1062-6050-43.2.144.

Handel, M., Horstmann, T., Dickhuth, H.-H., Gülch, R.W., 1997. Effects of contract-relax stretching training on muscle performance in athletes. Eur. J. Appl. Physiol. 76 (5), 400–408. http://dx.doi.org/10.1007/s004210050268.

Handsfield, G.G., Meyer, C.H., Hart, J.M., Abel, M.F., Blemker, S.S., 2014. Relationships of 35 lower limb muscles to height and body mass quantified using MRI. J. Biomech. 47 (3), 631–638. http://dx.doi.org/10.1016/j.jbiomech.2013.12.002.

Harris-Hayes, M., Mueller, M.J., Sahrmann, S.A., Bloom, N.J., Steger-May, K., Clohisy, J.C., Salsich, G.B., 2014. Persons with chronic hip joint pain exhibit reduced hip muscle strength. J. Orthop. Sport. Phys. Ther. 44 (11), 890–898. http://dx.doi.org/10.2519/jospt.2014.5268.

Hartmann, A., Knols, R., Murer, K., De Bruin, E.D., 2009. Reproducibility of an isokinetic strength-testing protocol of the knee and ankle in older adults. Gerontology 55 (3), 259–268. http://dx.doi.org/10.1159/000172832.

Hartsell, H.D., 1994. Isokinetics and muscle strength ratios of the ankle invertors/evertors: A pilot study. Isokinet. Exerc. Sci. 4 (3), 116–121. http://dx.doi.org/10.3233/IES-1994-4306.

Hartsell, H.D., Spaulding, S.J., 1999. Eccentric/concentric ratios at selected velocities for the invertor and evertor muscles of the chronically unstable ankle. Br. J. Sports Med. 33 (4), 255–258. http://dx.doi.org/10.1136/bjsm.33.4.255.

Harzing, A.-W., 2010. The Publish or Perish Book: Your Guide to Effective and Responsible Citation Analysis. Tarma Software Research Pty Ltd.

Hasson, C.J., Miller, R.H., Caldwell, G.E., 2011. Contractile and elastic ankle joint muscular properties in young and older adults. PLoS One 6 (1), e15953. http://dx.doi.org/10.1371/journal.pone.0015953.

Hauraix, H., Nordez, A., Guilhem, G., Rabita, G., Dorel, S., 2015. In vivo maximal fascicle-shortening velocity during plantar flexion in humans. J. Appl. Physiol. 119 (11), 1262–1271. http://dx.doi.org/10.1152/japplphysiol.00542.2015.

Heerkens, Y., Woittiez, R., Huijing, P., van Ingen Schenau, G., Rozendal, R., Huson, A., 1985. Inter-individual differences in the passive resistance of the human knee. Hum. Mov. Sci. 4 (3), 167–188. http://dx.doi.org/10.1016/0167-9457(85)90001-6.

Henriksen, M., Rosager, S., Aaboe, J., Graven-Nielsen, T., Bliddal, H., 2011. Experimental knee pain reduces muscle strength. J. Pain 12 (4), 460–467. http://dx.doi.org/10.1016/j.jpain.2010.10.004.

Herda, T.J., Cramer, J.T., Ryan, E.D., McHugh, M.P., Stout, J.R., 2008. Acute effects of static versus dynamic stretching on isometric peak torque, electromyography, and mechanomyography of the biceps femoris muscle. J. Strength Cond. Res. 22 (3), 809–817. http://dx.doi.org/10.1519/JSC.0b013e31816a82ec.

Herzog, W., Leonard, T., Wu, J., 2000. The relationship between force depression following shortening and mechanical work in skeletal muscle. J. Biomech. 33 (6), 659–668. http://dx.doi.org/10.1016/S0021-9290(00)00008-7.

Herzog, W., Read, L., ter Keurs, H., 1991. Experimental determination of force–length relations of intact human gastrocnemius muscles. Clin. Biomech. 6 (4), 230–238. http://dx.doi.org/10.1016/0268-0033(91)90051-Q.

Herzog, W., ter Keurs, H.E.D.J., 1988. A method for the determination of the force–length relation of selected in-vivo human skeletal muscles. Pflügers Arch. 411 (6), 637–641. http://dx.doi.org/10.1007/BF00580859.

Hester, J.T., Falkel, J.E., 1984. Isokinetic evaluation of tibial rotation: Assessment of a stabilization technique. J. Orthop. Sport. Phys. Ther. 6 (1), 46–51. http://dx.doi.org/10.2519/jospt.1984.6.1.46.

Hiemstra, L.A., Webber, S., MacDonald, P.B., Kriellaars, D.J., 2007. Contralateral limb strength deficits after anterior cruciate ligament reconstruction using a hamstring tendon graft. Clin. Biomech. 22 (5), 543–550. http://dx.doi.org/10.1016/j.clinbiomech.2007.01.009.

Hill, A.V., 1938. The heat of shortening and the dynamic constants of muscle. Proc. R. Soc. Lond. Ser. B - Biol. Sci. 126 (843), 136–195. http://dx.doi.org/10.1098/rspb.1938.0050.

Hirata, K., Kanehisa, H., Miyamoto, N., 2017. Acute effect of static stretching on passive stiffness of the human gastrocnemius fascicle measured by ultrasound shear wave elastography. Eur. J. Appl. Physiol. 117 (3), 493–499. http://dx.doi.org/10.1007/s00421-017-3550-z.

Hirata, K., Miyamoto-Mikami, E., Kanehisa, H., Miyamoto, N., 2016. Muscle-specific acute changes in passive stiffness of human triceps surae after stretching. Eur. J. Appl. Physiol. 116 (5), 911–918. http://dx.doi.org/10.1007/s00421-016-3349-3.

Hisaeda, H., Shinohara, M., Kouzaki, M., Fukunaga, T., 2001. Effect of local blood circulation and absolute torque on muscle endurance at two different knee-joint angles in humans. Eur. J. Appl. Physiol. 86 (1), 17–23. http://dx.doi.org/10.1007/s004210100497.

Holzbaur, K.R.S., Murray, W.M., Delp, S.L., 2005. A model of the upper extremity for simulating musculoskeletal surgery and analyzing neuromuscular control. Ann. Biomed. Eng. 33 (6), 829–840. http://dx.doi.org/10.1007/s10439-005-3320-7.

Holzer, D., Millard, M., Hahn, D., Siebert, T., Schwirtz, A., Seiberl, W., 2023. Tendon compliance and preload must be considered when determining the in vivo force–velocity relationship from the torque–angular velocity relation. Sci. Rep. 13 (1), 6588. http://dx.doi.org/10.1038/s41598-023-33643-9.

Holzer, D., Paternoster, F.K., Hahn, D., Siebert, T., Seiberl, W., 2020. Considerations on the human Achilles tendon moment arm for in vivo triceps surae muscle–tendon unit force estimates. Sci. Rep. 10 (1), 19559. http://dx.doi.org/10.1038/s41598-020-76625-x.

Hopkins, J., Sitler, M., Ryan, J., 1993. The effects of hip position and angular velocity on quadriceps and hamstring eccentric peak torque and ham/quad ratio. Isokinet. Exerc. Sci. 3 (1), 27–33. http://dx.doi.org/10.3233/IES-1993-3104.

Hornsby, T.M., Nicholson, G.G., Gossman, M.R., Culpepper, M., 1987. Effect of inherent muscle length on isometric plantar flexion torque in healthy women. Phys. Ther. 67 (8), 1191–1197. http://dx.doi.org/10.1093/ptj/67.8.1191.

Horstman, A., Gerrits, K., Beltman, M., Janssen, T., Konijnenbelt, M., de Haan, A., 2009. Muscle function of knee extensors and flexors after stroke is selectively impaired at shorter muscle lengths. J. Rehabil. Med. 41 (5), 317–321. http://dx.doi.org/10.2340/16501977-0331.

Horstmann, T., Maschmann, J., Mayer, F., Heitkamp, H.-C., Handel, M., Dickhuth, H.-H., 1999. The influence of age on isokinetic torque of the upper and lower leg musculature in sedentary men. Int. J. Sports Med. 20 (06), 362–367. http://dx.doi.org/10.1055/s-2007-971145.

Horstmann, T., Mayer, F., Maschmann, J., Niess, A., Roecker, K., Dickhuth, H.-H., 2001. Metabolic reaction after concentric and eccentric endurance-exercise of the knee and ankle. Med. Sci. Sports Exerc. 33 (5), 791–795. http://dx.doi.org/10.1097/00005768-200105000-00018.

Hu, T., Kühn, J., Haddadin, S., 2020. Forward and inverse dynamics modeling of human shoulder–arm musculoskeletal system with scapulothoracic constraint. Comput. Methods Biomech. Biomed. Eng. 23 (11), 785–803. http://dx.doi.org/10.1080/10255842.2020.1764945.

Hussain, S.J., Frey-Law, L., 2016. 3D strength surfaces for ankle plantar- and dorsi-flexion in healthy adults: An isometric and isokinetic dynamometry study. J. Foot Ankle Res. 9 (1), 43. http://dx.doi.org/10.1186/s13047-016-0174-1.

Ichinose, Y., Kawakami, Y., Ito, M., Kanehisa, H., Fukunaga, T., 2000. In vivo estimation of contraction velocity of human vastus lateralis muscle during "isokinetic" action. J. Appl. Physiol. 88 (3), 851–856. http://dx.doi.org/10.1152/jappl.2000.88.3.851.

Iwamoto, H., Sugaya, R., Sugi, H., 1990. Force–velocity relation of frog skeletal muscle fibres shortening under continuously changing load. J. Physiol. 422 (1), 185–202. http://dx.doi.org/10.1113/jphysiol.1990.sp017979.

Jeon, K., Chun, S., Seo, B., 2016. Effects of muscle strength asymmetry between left and right on isokinetic strength of the knee and ankle joints depending on athletic performance level. J. Phys. Ther. Sci. 28 (4), 1289–1293. http://dx.doi.org/10.1589/jpts.28.1289.

Jeon, H.-S., Trimble, M.H., Brunt, D., Robinson, M.E., 2001. Facilitation of quadriceps activation following a concentrically controlled knee flexion movement: The influence of transition rate. J. Orthop. Sport. Phys. Ther. 31 (3), 122–132. http://dx.doi.org/10.2519/jospt.2001.31.3.122.

Jiroumaru, T., Kurihara, T., Isaka, T., 2014. Measurement of muscle length–related electromyography activity of the hip flexor muscles to determine individual muscle contributions to the hip flexion torque. SpringerPlus 3 (1), 624. http://dx.doi.org/10.1186/2193-1801-3-624.

Johnson, S., Hoffman, M., 2010. Isometric hip-rotator torque production at varying degrees of hip flexion. J. Sport. Rehabil. 19 (1), 12–20. http://dx.doi.org/10.1123/jsr.19.1.12.

Jones, P., Bampouras, T.M., Marrin, K., 2009. An investigation into the physical determinants of change of direction speed. J. Sport. Med. Phys. Fit. 49 (1), 97–104.

Kaminski, T.W., Dover, G.C., 2001. Reliability of inversion and eversion peak- and average-torque measurements from the biodex system 3 dynamometer. J. Sport. Rehabil. 10 (3), 205–220. http://dx.doi.org/10.1123/jsr.10.3.205.

Kaminski, T.W., Perrin, D.H., Gansneder, B.M., 1999. Eversion strength analysis of uninjured and functionally unstable ankles. J. Athl. Train. 34 (3), 239–245.

Kaneda, H., Takahira, N., Tsuda, K., Tozaki, K., Kudo, S., Takahashi, Y., Sasaki, S., Kenmoku, T., 2020. Effects of tissue flossing and dynamic stretching on hamstring muscles function. J. Sport. Sci. Med. 19 (4), 681–689.

Karamanidis, K., Arampatzis, A., 2005. Mechanical and morphological properties of different muscle–tendon units in the lower extremity and running mechanics: Effect of aging and physical activity. J. Exp. Biol. 208 (20), 3907–3923. http://dx.doi.org/10.1242/jeb.01830.

Kato, E., Kanehisa, H., Fukunaga, T., Kawakami, Y., 2010. Changes in ankle joint stiffness due to stretching: The role of tendon elongation of the gastrocnemius muscle. Eur. J. Sport. Sci. 10 (2), 111–119. http://dx.doi.org/10.1080/17461390903307834.

Kato, T., Taniguchi, K., Kikukawa, D., Kodesho, T., Katayose, M., 2021. Effect of hip flexion angle on stiffness of the adductor longus muscle during isometric hip flexion. J. Electromyography Kinesiol. 56, 102493. http://dx.doi.org/10.1016/j.jelekin.2020.102493.

Kato, T., Taniguchi, K., Kodesho, T., Nakao, G., Yokoyama, Y., Saito, Y., Katayose, M., 2023. Quantifying the shear modulus of the adductor longus muscle during hip joint motion using shear wave elastography. Sci. Rep. 13 (1), 9510. http://dx.doi.org/10.1038/s41598-023-36698-w.

Kaufman, K.R., An, K.-N., Chao, E.Y., 1995. A comparison of intersegmental joint dynamics to isokinetic dynamometer measurements. J. Biomech. 28 (10), 1243–1256. http://dx.doi.org/10.1016/0021-9290(94)00176-5.

Kawakami, Y., Ichinose, Y., Fukunaga, T., 1998a. Architectural and functional features of human triceps surae muscles during contraction. J. Appl. Physiol. 85 (2), 398–404. http://dx.doi.org/10.1152/jappl.1998.85.2.398.

Kawakami, Y., Sale, D.G., MacDougall, J.D., Moroz, J.S., 1998b. Bilateral deficit in plantar flexion: Relation to knee joint position, muscle activation, and reflex excitability. Eur. J. Appl. Physiol. 77 (3), 212–216. http://dx.doi.org/10.1007/s004210050324.

Kazazović, E., Tabaković, M., Talović, M., Alić, H., Jelešković, E., Mrković, R., 2010. Evaluation of knee muscles isokinetic evaluation between professional and amateur athletes first year students of the faculty of sport and physical education. Homosporticus 12 (2).

Kellis, E., 2001. Tibiofemoral joint forces during maximal isokinetic eccentric and concentric efforts of the knee flexors. Clin. Biomech. 16 (3), 229–236. http://dx.doi.org/10.1016/S0268-0033(00)00084-X.

Kellis, E., 2019. Antagonist muscle architecture and aponeurosis/tendon strain of biceps femoris long head during maximal isometric efforts. Eur. J. Appl. Physiol. 119 (1), 73–83. http://dx.doi.org/10.1007/s00421-018-4000-2.

Kellis, E., Baltzopoulos, V., 1997. The effects of antagonist moment on the resultant knee joint moment during isokinetic testing of the knee extensors. Eur. J. Appl. Physiol. 76 (3), 253–259. http://dx.doi.org/10.1007/s004210050244.

Kellis, E., Galanis, N., Kofotolis, N., Hatzi, A., 2017. Effects of hip flexion angle on surface electromyographic activity of the biceps femoris and semitendinosus during isokinetic knee flexion. Muscle Ligaments Tendons J. 07 (02), 286–292. http://dx.doi.org/10.32098/mltj.02.2017.11.

Kennedy, P., Cresswell, A., 2001. The effect of muscle length on motor-unit recruitment during isometric plantar flexion in humans. Exp. Brain Res. 137 (1), 58–64. http://dx.doi.org/10.1007/s002210000623.

Khalaf, K.A., Parnianpour, M., Karakostas, T., 2000. Surface responses of maximum isokinetic ankle torque generation capability. J. Appl. Biomech. 16 (1), 52–59. http://dx.doi.org/10.1123/jab.16.1.52.

Kim, S., 1998. Muscle–ligament interactions at the human knee (I): Maximum isometric leg exercises. KSME Int. J. 12 (6), 1079–1089. http://dx.doi.org/10.1007/BF02942581.

Kim, K., Cha, Y.-J., Fell, D.W., 2016. Differential effects of ankle position on isokinetic knee extensor and flexor strength gains during strength training. Isokinet. Exerc. Sci. 24 (3), 195–199. http://dx.doi.org/10.3233/IES-160617.

Kim, K., Piao, Y.-J., Kim, N.-G., Kwon, T.-K., 2010. Characteristic analysis of the isokinetic strength in lower limbs of the elderly on training for postural control. Int. J. Precis. Eng. Manuf. 11 (6), 955–967. http://dx.doi.org/10.1007/s12541-010-0116-y.

Kindel, C., Challis, J., 2017. Joint moment–angle properties of the hip abductors and hip extensors. Physiother. Theory Pr. 33 (7), 568–575. http://dx.doi.org/10.1080/09593985.2017.1323357.

Kindel, C., Challis, J., 2018. Joint moment–angle properties of the hip extensors in subjects with and without patellofemoral pain. J. Appl. Biomech. 34 (2), 159–166. http://dx.doi.org/10.1123/jab.2017-0131.

Kitai, T.A., Sale, D.G., 1989. Specificity of joint angle in isometric training. Eur. J. Appl. Physiol. 58 (7), 744–748. http://dx.doi.org/10.1007/BF00637386.

Klass, M., Guissard, N., Duchateau, J., 2004. Limiting mechanisms of force production after repetitive dynamic contractions in human triceps surae. J. Appl. Physiol. 96 (4), 1516–1521. http://dx.doi.org/10.1152/japplphysiol.01049.2003.

Kluka, V., Martin, V., Vicencio, S.G., Giustiniani, M., Morel, C., Morio, C., Coudeyre, E., Ratel, S., 2016. Effect of muscle length on voluntary activation of the plantar flexors in boys and men. Eur. J. Appl. Physiol. 116 (5), 1043–1051. http://dx.doi.org/10.1007/s00421-016-3362-6.

Knapik, J.J., Wright, J.E., Mawdsley, R.H., Braun, J., 1983. Isometric, isotonic, and isokinetic torque variations in four muscle groups through a range of joint motion. Phys. Ther. 63 (6), 938–947. http://dx.doi.org/10.1093/ptj/63.6.938.

Koh, T.J., Herzog, W., 1995. Evaluation of voluntary and elicited dorsiflexor torque–angle relationships. J. Appl. Physiol. 79 (6), 2007–2013. http://dx.doi.org/10.1152/jappl.1995.79.6.2007.

Kong, Y., 2023. Effect of ballet dance on ankle joint muscle strength based on isokinetic research. Front. Sport. Res. 5 (6), 1–7. http://dx.doi.org/10.25236/FSR.2023.050601.

Konrad, A., Gad, M., Tilp, M., 2015. Effect of PNF stretching training on the properties of human muscle and tendon structures. Scand. J. Med. Sci. Sports 25 (3), 346–355. http://dx.doi.org/10.1111/sms.12228.

Konrad, A., Stafilidis, S., Tilp, M., 2017. Effects of acute static, ballistic, and PNF stretching exercise on the muscle and tendon tissue properties. Scand. J. Med. Sci. Sports 27 (10), 1070–1080. http://dx.doi.org/10.1111/sms.12725.

Konrad, A., Tilp, M., 2014. Increased range of motion after static stretching is not due to changes in muscle and tendon structures. Clin. Biomech. 29 (6), 636–642. http://dx.doi.org/10.1016/j.clinbiomech.2014.04.013.

Kordi Yoosefinejad, A., Khademi, S., Vosoughi, A.R., 2022. Consequences of extensile lateral approach to the calcaneal fractures on balance and isokinetic strength of muscle groups crossing the ankle joint. Foot Ankle Surg. 28 (6), 732–737. http://dx.doi.org/10.1016/j.fas.2021.09.001.

Krause, D.A., Neuger, M.D., Lambert, K.A., Johnson, A.E., DeVinny, H.A., Hollman, J.H., 2014. Effects of examiner strength on reliability of hip-strength testing using a handheld dynamometer. J. Sport. Rehabil. 23 (1), 56–64. http://dx.doi.org/10.1123/JSR.2012-0070.

Krylow, A.M., Sandercock, T.G., 1997. Dynamic force responses of muscle involving eccentric contraction. J. Biomech. 30 (1), 27–33. http://dx.doi.org/10.1016/S0021-9290(96)00097-8.

Kubo, K., Kanehisa, H., Fukunaga, T., 2001. Is passive stiffness in human muscles related to the elasticity of tendon structures? Eur. J. Appl. Physiol. 85 (3–4), 226–232. http://dx.doi.org/10.1007/s004210100463.

Kubo, K., Kanehisa, H., Fukunaga, T., 2002. Effects of resistance and stretching training programmes on the viscoelastic properties of human tendon structures *in vivo*. J. Physiol. 538 (1), 219–226. http://dx.doi.org/10.1113/jphysiol.2001.012703.

Kubo, K., Ohgo, K., Takeishi, R., Yoshinaga, K., Tsunoda, N., Kanehisa, H., Fukunaga, T., 2006a. Effects of isometric training at different knee angles on the muscle–tendon complex in vivo. Scand. J. Med. Sci. Sports 16 (3), 159–167. http://dx.doi.org/10.1111/j.1600-0838.2005.00450.x.

Kubo, K., Ohgo, K., Takeishi, R., Yoshinaga, K., Tsunoda, N., Kanehisa, H., Fukunaga, T., 2006b. Effects of series elasticity on the human knee extension torque-angle relationship in vivo. Res. Q. Exerc. Sport 77 (4), 408–416. http://dx.doi.org/10.1080/02701367.2006.10599376.

Kwon, Y.-J., Lee, H.-O., 2013. How different knee flexion angles influence the hip extensor in the prone position. J. Phys. Ther. Sci. 25 (10), 1295–1297. http://dx.doi.org/10.1589/jpts.25.1295.

Labarque, V., Op'T Eijnde, B., Van Leemputte, M., 2002. Effect of immobilization and retraining on torque–velocity relationship of human knee flexor and extensor muscles. Eur. J. Appl. Physiol. 86 (3), 251–257. http://dx.doi.org/10.1007/s00421-001-0530-z.

Lacerte, M., de Lateur, B.J., Alquist, A.D., Questad, K.A., 1992. Concentric versus combined concentric–eccentric isokinetic training programs: Effect on peak torque of human quadriceps femoris muscle. Arch. Phys. Med. Rehabil. 73 (11), 1059–1062.

Lanza, I.R., Towse, T.F., Caldwell, G.E., Wigmore, D.M., Kent-Braun, J.A., 2003. Effects of age on human muscle torque, velocity, and power in two muscle groups. J. Appl. Physiol. 95 (6), 2361–2369. http://dx.doi.org/10.1152/japplphysiol.00724.2002.

Lavin, R.P., Gross, M.T., 1990. Comparison of johnson anti-shear accessory and standard dynamometer attachment for anterior and posterior tibial translation during isometric muscle contractions. J. Orthop. Sport. Phys. Ther. 11 (11), 547–553. http://dx.doi.org/10.2519/jospt.1990.11.11.547.

Le Sant, G., Nordez, A., Andrade, R., Hug, F., Freitas, S., Gross, R., 2017. Stiffness mapping of lower leg muscles during passive dorsiflexion. J. Anat. 230 (5), 639–650. http://dx.doi.org/10.1111/joa.12589.

Lee, H.-D., Kim, S.-J., Lee, D.-Y., Kurihara, T., Lee, Y.-S., Kawakami, Y., 2010. Shift in optimal joint angle of the ankle dorsiflexors following eccentric exercise. Exp. Mech. 50 (5), 661–666. http://dx.doi.org/10.1007/s11340-009-9245-6.

Lemaire, A., Lisembart, A., Ritz, M., Rahmani, A., 2015. Evaluation of hip muscles using torque– and power–velocity relationships in chronic low back pain subjects. Phys. Med. Rehabil. - Int. 2 (7), 1059.

Lemaire, A., Ripamonti, M., Ritz, M., Rahmani, A., 2014. Agreement of three vs. eight isokinetic preset velocities to determine knee extensor torque– and power–velocity relationships. Isokinet. Exerc. Sci. 22 (1), 1–7. http://dx.doi.org/10.3233/IES-130524.

Levene, J.A., Hart, B.A., Seeds, R.H., Fuhrman, G.A., 1991. Reliability of reciprocal isokinetic testing of the knee extensors and flexors. J. Orthop. Sport. Phys. Ther. 14 (3), 121–127. http://dx.doi.org/10.2519/jospt.1991.14.3.121.

Light, N., Thorborg, K., 2016. The precision and torque production of common hip adductor squeeze tests used in elite football. J. Sci. Med. Sport. 19 (11), 888–892. http://dx.doi.org/10.1016/j.jsams.2015.12.009.

Locicero, R.D., 1991. The effect of electrical stimulation on isometric and lsokinetic knee extension torque: Interaction of the Kinestim electrical stimulator and the Cybex II+®. J. Orthop. Sport. Phys. Ther. 13 (3), 143–148. http://dx.doi.org/10.2519/jospt.1991.13.3.143.
Mademli, L., Arampatzis, A., Morey-Klapsing, G., Brüggemann, G.-P., 2004. Effect of ankle joint position and electrode placement on the estimation of the antagonistic moment during maximal plantarflexion. J. Electromyography Kinesiol. 14 (5), 591–597. http://dx.doi.org/10.1016/j.jelekin.2004.03.006.
Maffiuletti, N.A., Jubeau, M., Munzinger, U., Bizzini, M., Agosti, F., De Col, A., Lafortuna, C.L., Sartorio, A., 2007. Differences in quadriceps muscle strength and fatigue between lean and obese subjects. Eur. J. Appl. Physiol. 101 (1), 51–59. http://dx.doi.org/10.1007/s00421-007-0471-2.
Maffiuletti, N.A., Pensini, M., Martin, A., 2002. Activation of human plantar flexor muscles increases after electromyostimulation training. J. Appl. Physiol. 92 (4), 1383–1392. http://dx.doi.org/10.1152/japplphysiol.00884.2001.
Maganaris, C.N., 2003. Force–length characteristics of the in vivo human gastrocnemius muscle. Clin. Anat. 16 (3), 215–223. http://dx.doi.org/10.1002/ca.10064.
Maganaris, C.N., 2004. A predictive model of moment–angle characteristics in human skeletal muscle: Application and validation in muscles across the ankle joint. J. Theoret. Biol. 230 (1), 89–98. http://dx.doi.org/10.1016/j.jtbi.2004.04.025.
Maganaris, C., Baltzopoulos, V., Sargeant, A., 1998. Differences in human antagonistic ankle dorsiflexor coactivation between legs; can they explain the moment deficit in the weaker plantarflexor leg? Exp. Physiol. 83 (6), 843–855. http://dx.doi.org/10.1113/expphysiol.1998.sp004164.
Magnusson, S.P., Geismar, R.A., Gleim, G.W., Nicholas, J.A., 1993. The effect of stabilization on isokinetic knee extension and flexion torque production. J. Athl. Train. 28 (3), 221–225.
Mańka, J., Bobowik, P., Jaskulski, K., Wiszomirska, I., Kaczmarczyk, K., 2022. The influence of three different test positions and thigh asymmetry on measurements of isometric hip flexion strength in men and women. Acta Bioeng. Biomech. 24 (4), 49–56. http://dx.doi.org/10.37190/ABB-02160-2022-01.
Marsh, E., Sale, D., McComas, A.J., Quinlan, J., 1981. Influence of joint position on ankle dorsiflexion in humans. J. Appl. Physiol. 51 (1), 160–167. http://dx.doi.org/10.1152/jappl.1981.51.1.160.
Marshall, P.W., Lovell, R., Knox, M.F., Brennan, S.L., Siegler, J.C., 2015. Hamstring fatigue and muscle activation changes during six sets of nordic hamstring exercise in amateur soccer players. J. Strength Cond. Res. 29 (11), 3124–3133. http://dx.doi.org/10.1519/JSC.0000000000000966.
Marshall, R.N., Mazur, S.M., Taylor, N.A.S., 1990. Three-dimensional surfaces for human muscle kinetics. Eur. J. Appl. Physiol. 61 (3–4), 263–270. http://dx.doi.org/10.1007/BF00357610.
Martin, L., Cometti, G., Pousson, M., Morlon, B., 1994. The influence of electrostimulation on mechanical and morphological characteristics of the triceps surae. J. Sports Sci. 12 (4), 377–381. http://dx.doi.org/10.1080/02640419408732184.
Mashima, H., 1977. Force–load–velocity relation and the internal load of tetanized frog cardiac muscle. Jpn. J. Physiol. 27 (4), 483–499. http://dx.doi.org/10.2170/jjphysiol.27.483.
Mashima, H., Akazawa, K., Kushima, H., Fujii, K., 1972. The force–load–velocity relation and the viscous-like force in the frog skeletal muscle. Jpn. J. Physiol. 22 (1), 103–120. http://dx.doi.org/10.2170/jjphysiol.22.103.
McFaull, S.R., Lamontagne, M., 1998. In vivo measurement of the passive viscoelastic properties of the human knee joint. Hum. Mov. Sci. 17 (2), 139–165. http://dx.doi.org/10.1016/S0167-9457(97)00027-4.
McHugh, M.P., Hogan, D.E., 2004. Effect of knee flexion angle on active joint stiffness. Acta Physiol. Scand. 180 (3), 249–254. http://dx.doi.org/10.1046/j.0001-6772.2003.01240.x.
McHugh, M.P., Tetro, D.T., 2003. Changes in the relationship between joint angle and torque production associated with the repeated bout effect. J. Sports Sci. 21 (11), 927–932. http://dx.doi.org/10.1080/0264041031000140400.
Meijer, K., Bosch, P., Bobbert, M.F., van Soest, A.J., Huijing, P.A., 1998. The isometric knee extension moment–angle relationship: Experimental data and predictions based on cadaver data. J. Appl. Biomech. 14 (1), 62–79. http://dx.doi.org/10.1123/jab.14.1.62.
Melo, R.C., Takahashi, A.C., Quitério, R.J., Salvini, T.F., Catai, A.M., 2016. Eccentric torque-producing capacity is influenced by muscle length in older healthy adults. J. Strength Cond. Res. 30 (1), 259–266. http://dx.doi.org/10.1519/JSC.0000000000001047.
Milanezi, F.C., Marques, N.R., Cardozo, A.C., Gonçalves, M., 2015. Comparison of strength and proprioception parameters between subjects with and without functional ankle instability. Fisioter. E Pesqui. 22 (1), 23–28, doi:10.590/1809-2950/12675222012015.
Milner, T.E., Franklin, D.W., 2005. Impedance control and internal model use during the initial stage of adaptation to novel dynamics in humans. J. Physiol. 567 (2), 651–664. http://dx.doi.org/10.1113/jphysiol.2005.090449.
Miyamoto, N., Hirata, K., Kanehisa, H., 2017. Effects of hamstring stretching on passive muscle stiffness vary between hip flexion and knee extension maneuvers. Scand. J. Med. Sci. Sports 27 (1), 99–106. http://dx.doi.org/10.1111/sms.12620.
Miyamoto, N., Oda, S., 2003. Mechanomyographic and electromyographic responses of the triceps surae during maximal voluntary contractions. J. Electromyography Kinesiol. 13 (5), 451–459. http://dx.doi.org/10.1016/S1050-6411(03)00058-0.
Mohamed, O., Perry, J., Hislop, H., 2002. Relationship between wire EMG activity, muscle length, and torque of the hamstrings. Clin. Biomech. 17 (8), 569–579. http://dx.doi.org/10.1016/S0268-0033(02)00070-0.
Moltubakk, M.M., Magulas, M.M., Villars, F.O., Seynnes, O.R., Bojsen-Møller, J., 2018. Specialized properties of the triceps surae muscle–tendon unit in professional ballet dancers. Scand. J. Med. Sci. Sports 28 (9), 2023–2034. http://dx.doi.org/10.1111/sms.13207.
Moltubakk, M.M., Villars, F.O., Magulas, M.M., Magnusson, S.P., Seynnes, O.R., Bojsen-Møller, J., 2021. Altered triceps surae muscle–tendon unit properties after 6 months of static stretching. Med. Sci. Sport. Exerc. 53 (9), 1975–1986. http://dx.doi.org/10.1249/MSS.0000000000002671.
Morris, N., Jordan, M.J., Sumar, S., van Adrichem, B., Heard, M., Herzog, W., 2021. Joint angle–specific impairments in rate of force development, strength, and muscle morphology after hamstring autograft. Transl. Sport. Med. 4 (1), 104–114. http://dx.doi.org/10.1002/tsm2.189.
Morse, C.I., Degens, H., Seynnes, O.R., Maganaris, C.N., Jones, D.A., 2008. The acute effect of stretching on the passive stiffness of the human gastrocnemius muscle tendon unit. J. Physiol. 586 (1), 97–106. http://dx.doi.org/10.1113/jphysiol.2007.140434.
Morse, C.I., Thom, J.M., Birch, K.M., Narici, M.V., 2005. Tendon elongation influences the amplitude of interpolated doublets in the assessment of activation in elderly men. J. Appl. Physiol. 98 (1), 221–226. http://dx.doi.org/10.1152/japplphysiol.00774.2004.
Moseley, A.M., Crosbie, J., Adams, R., 2001. Normative data for passive ankle plantarflexion–dorsiflexion flexibility. Clin. Biomech. 16 (6), 514–521. http://dx.doi.org/10.1016/S0268-0033(01)00030-4.
Müller, S., Baur, H., König, T., Hirschmüller, A., Mayer, F., 2007. Reproducibility of isokinetic single- and multi-joint strength measurements in healthy and injured athletes. Isokinet. Exerc. Sci. 15 (4), 295–302. http://dx.doi.org/10.3233/IES-2007-0286.
Muraoka, T., Muramatsu, T., Takeshita, D., Kawakami, Y., Fukunaga, T., 2002. Length change of human gastrocnemius aponeurosis and tendon during passive joint motion. Cells Tissues Organs 171 (4), 260–268. http://dx.doi.org/10.1159/000063128.
Murphy, D.F., Connolly, D.A.J., Beynnon, B.D., 2003. Risk factors for lower extremity injury: A review of the literature. Br. J. Sports Med. 37 (1), 13–29. http://dx.doi.org/10.1136/bjsm.37.1.13.
Murray, M.P., Gardner, G.M., Mollinger, L.A., Sepic, S.B., 1980. Strength of isometric and isokinetic contractions: Knee muscles of men aged 20 to 86. Phys. Ther. 60 (4), 412–419. http://dx.doi.org/10.1093/ptj/60.4.412.
Nagy, P., Brogden, C., Greig, M., 2021. Isokinetic ankle eversion and inversion strength profiling of female ballet dancers. J. Sports Sci. 39 (1), 1–9. http://dx.doi.org/10.1080/02640414.2020.1803185.
Namazi, P., Zarei, M., Hovanloo, F., Abbasi, H., 2019. The association between the isokinetic muscle strength and lower extremity injuries in young male football players. Phys. Ther. Sport. 39, 76–81. http://dx.doi.org/10.1016/j.ptsp.2019.06.013.
Narici, M.V., Hoppeler, H., Kayser, B., Landoni, L., Claassen, H., Gavardi, C., Conti, M., Cerretelli, P., 1996. Human quadriceps cross-sectional area, torque and neural activation during 6 months strength training. Acta Physiol. Scand. 157 (2), 175–186. http://dx.doi.org/10.1046/j.1365-201X.1996.483230000.x.
Nelson, A.G., Guillory, I.K., Cornwell, C., Kokkonen, J., 2001. Inhibition of maximal voluntary isokinetic torque production following stretching is velocity-specific. J. Strength Cond. Res. 15 (2), 241–246.
Neumann, D.A., Soderberg, G.L., Cook, T.M., 1988. Comparison of maximal isometric hip abductor muscle torques between hip sides. Phys. Ther. 68 (4), 496–502. http://dx.doi.org/10.1093/ptj/68.4.496.
Nisell, R., Ericson, M.O., Nemeth, G., Ekholm, J., 1989. Tibiofemoral joint forces during isokinetic knee extension. Am. J. Sport. Med. 17 (1), 49–54. http://dx.doi.org/10.1177/036354658901700108.
Noorkõiv, M., Nosaka, K., Blazevich, A.J., 2015. Effects of isometric quadriceps strength training at different muscle lengths on dynamic torque production. J. Sports Sci. 33 (18), 1952–1961. http://dx.doi.org/10.1080/02640414.2015.1020843.
Nordez, A., Casari, P., Cornu, C., 2008. Effects of stretching velocity on passive resistance developed by the knee musculo–articular complex: Contributions of frictional and viscoelastic behaviours. Eur. J. Appl. Physiol. 103 (2), 243–250. http://dx.doi.org/10.1007/s00421-008-0695-9.
Novak, A.C., Brouwer, B., 2012. Strength and aerobic requirements during stair ambulation in persons with chronic stroke and healthy adults. Arch. Phys. Med. Rehabil. 93 (4), 683–689. http://dx.doi.org/10.1016/j.apmr.2011.10.009.
O'Brien, T.D., Reeves, N.D., Baltzopoulos, V., Jones, D.A., Maganaris, C.N., 2009. The effects of agonist and antagonist muscle activation on the knee extension moment–angle relationship in adults and children. Eur. J. Appl. Physiol. 106 (6), 849–856. http://dx.doi.org/10.1007/s00421-009-1088-4.
Oliveira, A.S., Corvino, R.B., Gonçalves, M., Caputo, F., Denadai, B.S., 2012. Maximal isokinetic peak torque and EMG activity determined by shorter ranges of motion. Hum. Mov. 13 (2), 102–108. http://dx.doi.org/10.2478/v10038-012-0010-9.
Oliveira, A.S.C., Gonçalves, M., 2009. Leg muscles recruitment pattern in soccer players and active individuals during isometric contractions. Electromyogr. Clin. Neurophysiol. 49 (2–3), 93–101.

Olmo, J., Jato, S., Benito, J., Martín, I., Dvir, Z., 2009. Identification of feigned ankle plantar and dorsiflexors weakness in normal subjects. J. Electromyography Kinesiol. 19 (5), 774–781. http://dx.doi.org/10.1016/j.jelekin.2008.02.001.

O'Neill, S., Barry, S., Watson, P., 2019. Plantarflexor strength and endurance deficits associated with mid-portion Achilles tendinopathy: The role of soleus. Phys. Ther. Sport. 37, 69–76. http://dx.doi.org/10.1016/j.ptsp.2019.03.002.

Palmer, T.B., Akehi, K., Thiele, R.M., Smith, D.B., Warren, A.J., Thompson, B.J., 2015. Dorsiflexion, plantar-flexion, and neutral ankle positions during passive resistance assessments of the posterior hip and thigh muscles. J. Athl. Train. 50 (5), 467–474. http://dx.doi.org/10.4085/1062-6050-49.6.04.

Pang, M.Y., Mak, M.K., 2012. Influence of contraction type, speed, and joint angle on ankle muscle weakness in Parkinson's disease: Implications for rehabilitation. Arch. Phys. Med. Rehabil. 93 (12), 2352–2359. http://dx.doi.org/10.1016/j.apmr.2012.06.004.

Pavol, M.J., Owings, T.M., Foley, K.T., Grabiner, M.D., 2002. Influence of lower extremity strength of healthy older adults on the outcome of an induced trip. J. Am. Geriatr. Soc. 50 (2), 256–262. http://dx.doi.org/10.1046/j.1532-5415.2002.50056.x.

Pelletier, C.A., Hicks, A.L., 2010. The length–tension relationship of human dorsiflexor and plantarflexor muscles after spinal cord injury. Spinal Cord 48 (3), 202–206. http://dx.doi.org/10.1038/sc.2009.106.

Perhonen, M., Komi, P.V., Häkkinen, K., von Bonsdorff, H., Partio, H., 1992. Strength training and neuromuscular function in elderly people with total knee endoprosthesis. Scand. J. Med. Sci. Sports 2 (4), 234–243. http://dx.doi.org/10.1111/j.1600-0838.1992.tb00349.x.

Pinniger, G.J., Cresswell, A.G., 2007. Residual force enhancement after lengthening is present during submaximal plantar flexion and dorsiflexion actions in humans. J. Appl. Physiol. 102 (1), 18–25. http://dx.doi.org/10.1152/japplphysiol.00565.2006.

Pinniger, G.J., Steele, J.R., Thorstensson, A., Cresswell, A.G., 2000. Tension regulation during lengthening and shortening actions of the human soleus muscle. Eur. J. Appl. Physiol. 81 (5), 375–383. http://dx.doi.org/10.1007/s004210050057.

Porter, M.M., Vandervoort, A.A., Kramer, J.F., 1997. Eccentric peak torque of the plantar and dorsiflexors is maintained in older women. J. Gerontol. Ser. A: Biol. Sci. Med. Sci. 52A (2), B125–B131. http://dx.doi.org/10.1093/gerona/52A.2.B125.

Poulis, S., Poulis, I., Soames, R., 2000. Torque characteristics of the ankle plantarflexors and dorsiflexors during eccentric and concentric contraction in healthy young males. Isokinet. Exerc. Sci. 8 (4), 195–202. http://dx.doi.org/10.3233/IES-2000-0051.

Poulmedis, P., 1985. Isokinetic maximal torque power of greek elite soccer players. J. Orthop. Sport. Phys. Ther. 6 (5), 293–295. http://dx.doi.org/10.2519/jospt.1985.6.5.293.

Raffalt, P.C., Alkjær, T., Simonsen, E.B., 2016. Joint dynamics and intra-subject variability during countermovement jumps in children and adults. J. Biomech. 49 (13), 2968–2974. http://dx.doi.org/10.1016/j.jbiomech.2016.07.010.

Raiteri, B.J., Lauret, L., Hahn, D., 2023. The force–length relation of the young adult human tibialis anterior. PeerJ 11, e15693. http://dx.doi.org/10.7717/peerj.15693.

Ranisavljev, I., Ilic, V., Markovic, S., Soldatovic, I., Stefanovic, D., Jaric, S., 2014. The relationship between hip, knee and ankle muscle mechanical characteristics and gait transition speed. Hum. Mov. Sci. 38, 47–57. http://dx.doi.org/10.1016/j.humov.2014.08.006.

Rassier, D.E., Minozzo, F.C., 2016. Length-dependent Ca^{2+} activation in skeletal muscle fibers from mammalians. Am. J. Physiol.-Cell Physiol. 311 (2), C201–C211. http://dx.doi.org/10.1152/ajpcell.00046.2016.

Reeves, N.D., Narici, M.V., Maganaris, C.N., 2004. In vivo human muscle structure and function: Adaptations to resistance training in old age. Exp. Physiol. 89 (6), 675–689. http://dx.doi.org/10.1113/expphysiol.2004.027797.

Reichard, L.B., Croisier, J.L., Malnati, M., Katz-Leurer, M., Dvir, Z., 2005. Testing knee extension and flexion strength at different ranges of motion: An isokinetic and electromyographic study. Eur. J. Appl. Physiol. 95 (4), 371–376. http://dx.doi.org/10.1007/s00421-005-0006-7.

Riener, R., Edrich, T., 1999. Identification of passive elastic joint moments in the lower extremities. J. Biomech. 32 (5), 539–544. http://dx.doi.org/10.1016/S0021-9290(99)00009-3.

Robertson, D., Wilson, J.-M.J., Pierre, T.A.S., 2008. Lower extremity muscle functions during full squats. J. Appl. Biomech. 24 (4), 333–339. http://dx.doi.org/10.1123/jab.24.4.333.

Rousanoglou, E.N., Herzog, W., Boudolos, K.D., 2010. Moment–angle relations in the initial time of contraction. Int. J. Sports Med. 31 (09), 651–655. http://dx.doi.org/10.1055/s-0030-1255114.

Rugg, S., Gregor, R., Mandelbaum, B., Chiu, L., 1990. In vivo moment arm calculations at the ankle using magnetic resonance imaging (MRI). J. Biomech. 23 (5), 495–501. http://dx.doi.org/10.1016/0021-9290(90)90305-M.

Sacchetti, M.S., Balducci, S., Bazzucchi, I., Carlucci, F., Di Palumbo, A.S., Haxhi, J., Conti, F., Di Biase, N., Calandriello, E., Pugliese, G., 2013. Neuromuscular dysfunction in diabetes: Role of nerve impairment and training status. Med. Sci. Sport. Exerc. 45 (1), 52–59. http://dx.doi.org/10.1249/MSS.0b013e318269f9bb.

Sale, D., Quinlan, J., Marsh, E., McComas, A.J., Belanger, A.Y., 1982. Influence of joint position on ankle plantarflexion in humans. J. Appl. Physiol. 52 (6), 1636–1642. http://dx.doi.org/10.1152/jappl.1982.52.6.1636.

Salsich, G.B., Mueller, M.J., Sahrmann, S.A., 2000. Passive ankle stiffness in subjects with diabetes and peripheral neuropathy versus an age-matched comparison group. Phys. Ther. 80 (4), 352–362. http://dx.doi.org/10.1093/ptj/80.4.352.

Salzman, A., Torburn, L., Perry, J., 1993. Contribution of rectus femoris and vasti to knee extension: An electromyographic study. Clin. Orthop. Relat. Res. 290, 236–243.

Sasaki, K., Toyama, S., Ishii, N., 2014. Length–force characteristics of in vivo human muscle reflected by supersonic shear imaging. J. Appl. Physiol. 117 (2), 153–162. http://dx.doi.org/10.1152/japplphysiol.01058.2013.

Sasaki, Y., Ueno, T., Taniguchi, H., Ohyama, T., 1998. Effect of teeth clenching on isometric and isokinetic strength of ankle plantar flexion. J. Med. Dent. Sci. 45 (1), 29–37. http://dx.doi.org/10.11480/jmds.450104.

Savage, G., Allen, T.J., Proske, U., 2015. The senses of active and passive forces at the human ankle joint. Exp. Brain Res. 233 (7), 2167–2180. http://dx.doi.org/10.1007/s00221-015-4287-8.

Savelberg, H.H.C.M., Meijer, K., 2003. Contribution of mono- and biarticular muscles to extending knee joint moments in runners and cyclists. J. Appl. Physiol. 94 (6), 2241–2248. http://dx.doi.org/10.1152/japplphysiol.01001.2002.

Schmitt, H., Kuni, B., Sabo, D., 2005. Influence of professional dance training on peak torque and proprioception at the ankle. Clin. J. Sport. Med. 15 (5), 331–339. http://dx.doi.org/10.1097/01.jsm.0000181437.41268.56.

Scott, S.H., Brown, I.E., Loeb, G.E., 1996. Mechanics of feline soleus: I. Effect of fascicle length and velocity on force output. J. Muscle Res. Cell Motil. 17 (2), 207–219. http://dx.doi.org/10.1007/BF00124243.

Shaffer, M.A., Okereke, E., Esterhai, J.L., Elliott, M.A., Walter, G.A., Yim, S.H., Vandenborne, K., 2000. Effects of immobilization on plantar-flexion torque, fatigue resistance, and functional ability following an ankle fracture. Phys. Ther. 80 (8), 769–780. http://dx.doi.org/10.1093/ptj/80.8.769.

Shenoy, S., Mishra, P., Sandhu, J., 2011. Peak torque and iEMG activity of quadriceps femoris muscle at three different knee angles in a collegiate population. J. Exerc. Sci. Fit. 9 (1), 40–45. http://dx.doi.org/10.1016/S1728-869X(11)60005-1.

Shi, F., Rymer, W.Z., Son, J., 2021. Mechanomyogram amplitude vs. isometric ankle plantarflexion torque of human medial gastrocnemius muscle at different ankle joint angles. J. Electromyography Kinesiol. 61, 102609. http://dx.doi.org/10.1016/j.jelekin.2021.102609.

Silder, A., Whittington, B., Heiderscheit, B., Thelen, D.G., 2007. Identification of passive elastic joint moment–angle relationships in the lower extremity. J. Biomech. 40 (12), 2628–2635. http://dx.doi.org/10.1016/j.jbiomech.2006.12.017.

Silva, J.R.L.C., Detanico, D., Dal Pupo, J., Freitas, C.D.L.R., 2015. Bilateral asymmetry of knee and ankle isokinetic torque in soccer players u20 category. Rev. Bras. Cineantropometria Desempenho Hum. 17 (2), 195. http://dx.doi.org/10.5007/1980-0037.2015v17n2p195.

Simoneau, E., Martin, A., Van Hoecke, J., 2007. Effects of joint angle and age on ankle dorsi- and plantar-flexor strength. J. Electromyography Kinesiol. 17 (3), 307–316. http://dx.doi.org/10.1016/j.jelekin.2006.04.005.

Şimşek, D., Kirkaya, İ., Onarici Güngör, E., Soylu, A.R., 2016. Relationships among vertical jumping performance, EMG activation, and knee extensor and flexor muscle strength in turkish elite male volleyball players. Turk. Klin. J. Sport. Sci. 8 (2), 46–56. http://dx.doi.org/10.5336/sportsci.2016-51433.

Sleivert, G.G., Wenger, H.A., 1994. Reliability of measuring isometric and isokinetic peak torque, rate of torque development, integrated electromyography, and tibial nerve conduction velocity. Arch. Phys. Med. Rehabil. 75 (12), 1315–1321. http://dx.doi.org/10.1016/0003-9993(94)90279-8.

Smidt, G.L., 1973. Biomechanical analysis of knee flexion and extension. J. Biomech. 6 (1), 79–92. http://dx.doi.org/10.1016/0021-9290(73)90040-7.

Snook, A.G., 2001. The relationship between excessive pronation as measured by navicular drop and isokinetic strength of the ankle musculature. Foot Ankle Int. 22 (3), 234–240. http://dx.doi.org/10.1177/107110070102200311.

Sole, G., Hamrén, J., Milosavljevic, S., Nicholson, H., Sullivan, S.J., 2007. Test-retest reliability of isokinetic knee extension and flexion. Arch. Phys. Med. Rehabil. 88 (5), 626–631. http://dx.doi.org/10.1016/j.apmr.2007.02.006.

Stotz, A., Maghames, E., Mason, J., Groll, A., Zech, A., 2022. Maximum isometric torque at individually-adjusted joint angles exceeds eccentric and concentric torque in lower extremity joint actions. BMC Sport. Sci. Med. Rehabil. 14 (1), 13. http://dx.doi.org/10.1186/s13102-022-00401-9.

Styf, J., Ballard, R., Aratow, M., Crenshaw, A., Watenpaugh, D., Hargens, A.R., 1995. Intramuscular pressure and torque during isometric, concentric and eccentric muscular activity. Scand. J. Med. Sci. Sports 5 (5), 291–296. http://dx.doi.org/10.1111/j.1600-0838.1995.tb00047.x.

Suter, E., Herzog, W., De Souza, K., Bray, R., 1998. Inhibition of the quadriceps muscles in patients with anterior knee pain. J. Appl. Biomech. 14 (4), 360–373. http://dx.doi.org/10.1123/jab.14.4.360.

Svantesson, U., Grimby, G., Thomeé, R., 1994. Potentiation of concentric plantar flexion torque following eccentric and isometric muscle actions. Acta Physiol. Scand. 152 (3), 287–293. http://dx.doi.org/10.1111/j.1748-1716.1994.tb09808.x.

Tafazzoli, F., Lamontagne, M., 1996. Mechanical behaviour of hamstring muscles in low-back pain patients and control subjects. Clin. Biomech. 11 (1), 16–24. http://dx.doi.org/10.1016/0268-0033(95)00038-0.

Tankevicius, G., Lankaite, D., Krisciunas, A., 2013. Test-retest reliability of Biodex system 4 Pro for isometric ankle-eversion and -inversion measurement. J. Sport. Rehabil. 22 (3), 212–215. http://dx.doi.org/10.1123/jsr.22.3.212.

Taylor, N.A.S., Cotter, J.D., Stanley, S.N., Marshall, R.N., 1991. Functional torque–velocity and power-velocity characteristics of elite athletes. Eur. J. Appl. Physiol. 62 (2), 116–121. http://dx.doi.org/10.1007/BF00626766.

Thomeé, R., Renström, P., Karlsson, J., Grimby, G., 1995. Patellofemoral pain syndrome in young women: II. Muscle function in patients and healthy controls. Scand. J. Med. Sci. Sports 5 (4), 245–251. http://dx.doi.org/10.1111/j.1600-0838.1995.tb00041.x.

Thonnard, J., Bragard, D., Willems, P., Plaghki, L., 1996. Stability of the braced ankle: A biomechanical investigation. Am. J. Sport. Med. 24 (3), 356–361. http://dx.doi.org/10.1177/036354659602400318.

Tilp, M., Steib, S., Schappacher-Tilp, G., Herzog, W., 2011. Changes in fascicle lengths and pennation angles do not contribute to residual force enhancement/depression in voluntary contractions. J. Appl. Biomech. 27 (1), 64–73. http://dx.doi.org/10.1123/jab.27.1.64.

T'Jonck, L., Lysens, R., Witvrouw, E., Hulens, M., Delvaux, K., Peers, K., 1997. The effect of positioning, sex and leg dominance on the plantar and dorsal flexors strength at the ankle. Isokinet. Exerc. Sci. 6 (4), 235–241. http://dx.doi.org/10.3233/IES-1997-6406.

Toft, E., Espersen, G.T., Kålund, S., Sinkjær, T., Hornemann, B.C., 1989. Passive tension of the ankle before and after stretching. Am. J. Sport. Med. 17 (4), 489–494. http://dx.doi.org/10.1177/036354658901700407.

Tourny-Chollet, C., Leroy, D., 2002. Conventional vs. dynamic hamstring-quadriceps strength ratios: A comparison between players and sedentary subjects. Isokinet. Exerc. Sci. 10 (4), 183–192. http://dx.doi.org/10.3233/IES-2002-0102.

Tourny-Chollet, C., Leroy, D., Léger, H., Beuret-Blanquart, F., 2000. Isokinetic knee muscle strength of soccer players according to their position. Isokinet. Exerc. Sci. 8 (4), 187–193. http://dx.doi.org/10.3233/IES-2000-0050.

Trezise, J., Blazevich, A.J., 2019. Anatomical and neuromuscular determinants of strength change in previously untrained men following heavy strength training. Front. Physiol. 10, 1001. http://dx.doi.org/10.3389/fphys.2019.01001.

Tsaopoulos, D.E., Baltzopoulos, V., Richards, P.J., Maganaris, C.N., 2009. A comparison of different two-dimensional approaches for the determination of the patellar tendon moment arm length. Eur. J. Appl. Physiol. 105 (5), 809–814. http://dx.doi.org/10.1007/s00421-008-0968-3.

Tsaopoulos, D.E., Baltzopoulos, V., Richards, P.J., Maganaris, C.N., 2011. Mechanical correction of dynamometer moment for the effects of segment motion during isometric knee-extension tests. J. Appl. Physiol. 111 (1), 68–74. http://dx.doi.org/10.1152/japplphysiol.00821.2010.

Tsiokanos, A., Kellis, E., Jamurtas, A., Kellis, S., 2002. The relationship between jumping performance and isokinetic strength of hip and knee extensors and ankle plantar flexors. Isokinet. Exerc. Sci. 10 (2), 107–115. http://dx.doi.org/10.3233/IES-2002-0092.

Turpin, N.A., Costes, A., Villeger, D., Watier, B., 2014. Selective muscle contraction during plantarflexion is incompatible with maximal voluntary torque assessment. Eur. J. Appl. Physiol. 114 (8), 1667–1677. http://dx.doi.org/10.1007/s00421-014-2900-3.

Ueno, H., Suga, T., Takao, K., Tanaka, T., Misaki, J., Miyake, Y., Nagano, A., Isaka, T., 2018. Potential relationship between passive plantar flexor stiffness and running performance. Int. J. Sports Med. 39 (03), 204–209. http://dx.doi.org/10.1055/s-0043-121271.

Uritani, D., Fukumoto, T., 2012. Differences of isometric internal and external hip rotation torques among three different hip flexion positions. J. Phys. Ther. Sci. 24 (9), 863–865. http://dx.doi.org/10.1589/jpts.24.863.

Vagner, M., Malecek, J., Tomšovský, L., Kubový, P., Levitova, A., Stastny, P., 2019. Isokinetic strength of rotators, flexors and hip extensors is strongly related to front kick dynamics in military professionals. J. Hum. Kinet. 68 (1), 145–155. http://dx.doi.org/10.2478/hukin-2019-0063.

Valamatos, M.J., Tavares, F., Santos, R.M., Veloso, A.P., Mil-Homens, P., 2018. Influence of full range of motion vs. equalized partial range of motion training on muscle architecture and mechanical properties. Eur. J. Appl. Physiol. 118 (9), 1969–1983. http://dx.doi.org/10.1007/s00421-018-3932-x.

van Eijden, T., Weijs, W., Kouwenhoven, E., Verburg, J., 1987. Forces acting on the patella during maximal voluntary contraction of the quadriceps femoris muscle at different knee flexion/extension angles. Cells Tissues Organs 129 (4), 310–314. http://dx.doi.org/10.1159/000146421.

van Schaik, C.S., Hicks, A.L., McCartney, N., 1994. An evaluation of the length–tension relationship in elderly human ankle dorsiflexors. J. Gerontol. 49 (3), B121–B127. http://dx.doi.org/10.1093/geronj/49.3.B121.

Vandervoort, A.A., Kramer, J.F., Wharram, E.R., 1990. Eccentric knee strength of elderly females. J. Gerontol. 45 (4), B125–B128. http://dx.doi.org/10.1093/geronj/45.4.B125.

Vassis, K., Kanellopoulos, A.K., Misiris, I., Trigkas, P., Spanos, S., Poulis, I.A., 2020. Knee isokinetic test scores and functional hop tests findings: Are they related? Isokinet. Exerc. Sci. 28 (3), 231–238. http://dx.doi.org/10.3233/IES-192204.

Vinti, M., Couillandre, A., Hausselle, J., Bayle, N., Primerano, A., Merlo, A., Hutin, E., Gracies, J.-M., 2013. Influence of effort intensity and gastrocnemius stretch on co-contraction and torque production in the healthy and paretic ankle. Clin. Neurophysiol. 124 (3), 528–535. http://dx.doi.org/10.1016/j.clinph.2012.08.010.

Wang, R., Yan, S., Schlippe, M., Tarassova, O., Pennati, G.V., Lindberg, F., Körting, C., Destro, A., Yang, L., Shi, B., Arndt, A., 2021. Passive mechanical properties of human medial gastrocnemius and soleus musculotendinous unit. BioMed Res. Int. 2021, 1–12. http://dx.doi.org/10.1155/2021/8899699.

Ward, S.R., Eng, C.M., Smallwood, L.H., Lieber, R.L., 2009. Are current measurements of lower extremity muscle architecture accurate? Clin. Orthop. Relat. Res. 467 (4), 1074–1082. http://dx.doi.org/10.1007/s11999-008-0594-8.

Waugh, C.M., Blazevich, A.J., Fath, F., Korff, T., 2012. Age-related changes in mechanical properties of the Achilles tendon. J. Anat. 220 (2), 144–155. http://dx.doi.org/10.1111/j.1469-7580.2011.01461.x.

Webber, S.C., Porter, M.M., 2010. Reliability of ankle isometric, isotonic, and isokinetic strength and power testing in older women. Phys. Ther. 90 (8), 1165–1175. http://dx.doi.org/10.2522/ptj.20090394.

Weir, J.P., Evans, S.A., Housh, M.L., 1996a. The effect of extraneous movements on peak torque and constant joint angle torque-velocity curves. J. Orthop. Sport. Phys. Ther. 23 (5), 302–308. http://dx.doi.org/10.2519/jospt.1996.23.5.302.

Weir, J.P., McDonough, A.L., Hill, V.J., 1996b. The effects of joint angle on electromyographic indices of fatigue. Eur. J. Appl. Physiol. 73 (3–4), 387–392. http://dx.doi.org/10.1007/BF02425504.

Weiss, P., Kearney, R., Hunter, I., 1986. Position dependence of ankle joint dynamics—I. Passive mechanics. J. Biomech. 19 (9), 727–735. http://dx.doi.org/10.1016/0021-9290(86)90196-X.

Westing, S., Seger, J., 1989. Eccentric and concentric torque–velocity characteristics, torque output comparisons, and gravity effect torque corrections for the quadriceps and hamstring muscles in females. Int. J. Sports Med. 10 (03), 175–180. http://dx.doi.org/10.1055/s-2007-1024896.

Westing, S.H., Seger, J.Y., Karlson, E., Ekblom, B., 1988. Eccentric and concentric torque–velocity characteristics of the quadriceps femoris in man. Eur. J. Appl. Physiol. 58 (1–2), 100–104. http://dx.doi.org/10.1007/BF00636611.

Wiemann, K., Hahn, K., 1997. Influences of strength, stretching and circulatory exercises on flexibility parameters of the human hamstrings. Int. J. Sports Med. 18 (05), 340–346. http://dx.doi.org/10.1055/s-2007-972643.

Willems, T.M., Witvrouw, E., Delbaere, K., Mahieu, N., De Bourdeaudhuij, L., De Clercq, D., 2005a. Intrinsic risk factors for inversion ankle sprains in male subjects: A prospective study. Am. J. Sport. Med. 33 (3), 415–423. http://dx.doi.org/10.1177/0363546504268137.

Willems, T.M., Witvrouw, E., Delbaere, K., Philippaerts, R., De Bourdeaudhuij, I., De Clercq, D., 2005b. Intrinsic risk factors for inversion ankle sprains in females—A prospective study. Scand. J. Med. Sci. Sports 15 (5), 336–345. http://dx.doi.org/10.1111/j.1600-0838.2004.00428.x.

Willems, T., Witvrouw, E., Verstuyft, J., Vaes, P., De Clercq, D., 2002. Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. J. Athl. Train. 37 (4), 487–493.

Winegard, K.J., Hicks, A.L., Vandervoort, A.A., 1997. An evaluation of the length–tension relationship in elderly human plantarflexor muscles. J. Gerontol. Ser. A: Biol. Sci. Med. Sci. 52A (6), B337–B343. http://dx.doi.org/10.1093/gerona/52A.6.B337.

Wu, G., Siegler, S., Allard, P., Kirtley, C., Leardini, A., Rosenbaum, D., Whittle, M., D'Lima, D.D., Cristofolini, L., Witte, H., Schmid, O., Stokes, I., 2002. ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion—part I: Ankle, hip, and spine. J. Biomech. 35 (4), 543–548. http://dx.doi.org/10.1016/S0021-9290(01)00222-6.

Wu, X., Zhang, S., Liu, Y., Zhang, D., Xie, B., 2013. Do knee concentric and eccentric strength and sagittal-plane knee joint biomechanics differ between jumpers and non-jumpers in landing? Hum. Mov. Sci. 32 (6), 1299–1309. http://dx.doi.org/10.1016/j.humov.2013.03.008.

Yamaguchi, G.T., 2001. Dynamic Modeling of Musculoskeletal Motion: A Vectorized Approach for Biomechanical Analysis in Three Dimensions. Springer US, http://dx.doi.org/10.1007/978-0-387-28750-8.

Yokozawa, T., Kumagawa, D., Arakawa, H., Katsumata, Y., Akagi, R., 2019. A biomechanical analysis of the relationship between the joint powers during the standing long jump and maximum isokinetic strength of the lower limb joints. Int. J. Sport. Heal. Sci. 17, 13–24. http://dx.doi.org/10.5432/ijshs.201827.

Yoon, T.S., Park, D.S., Kang, S.W., Chun, S.I., Shin, J.S., 1991. Isometric and isokinetic torque curves at the knee joint. Yonsei Med. J. 32 (1), 33–43. http://dx.doi.org/10.3349/ymj.1991.32.1.33.

Zajac, F.E., 1993. Muscle coordination of movement: A perspective. J. Biomech. 26 (S1), 109–124. http://dx.doi.org/10.1016/0021-9290(93)90083-Q.

Zakas, A., Galazoulas, C., Doganis, G., Zakas, N., 2006. Effect of two acute static stretching durations of the rectus femoris muscle on quadriceps isokinetic peak torque in professional soccer players. Isokinet. Exerc. Sci. 14 (4), 357–362. http://dx.doi.org/10.3233/IES-2006-0249.

Zhang, L.-Q., Xu, D., Wang, G., Hendrix, R.W., 2001. Muscle strength in knee varus and valgus. Med. Sci. Sports Exerc. 33 (7), 1194–1199. http://dx.doi.org/10.1097/00005768-200107000-00018.