Asymmetry of Inter-joint Coordination during Single Leg Jump after Anterior Cruciate Ligament Reconstruction

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ABSTRACT

A little is known about the contralateral asymmetry in inter-joint coordination after anterior cruciate ligament reconstruction (ACL-R) during multi-segmental movements. This study aimed to evaluate inter-joint coordination asymmetry between the injured (IL) and non-injured leg (NIL) in patients after ACL-R during single-leg jumping. Twelve male patients having undergone ACL-R (7.3 months post-surgery) and 12 healthy males performed maximal vertical single-leg jumps with the right and left leg. The kinematics of each jump were recorded. The inter-joint coordination between the ankle, knee and hip joints was assessed by computing the continuous relative phase (CRP) and its variability. The effect of the group and leg was tested with a mixed linear model. The CRP and its variability were similar between the dominant and non-dominant leg of the healthy group. By contrast the CRP of the coupling ankle/knee and ankle/hip was smaller ($p<0.01$) for IL in comparison to NIL in the ACL-R group (-30% and -22% respectively). The CRP variability of the couplings ankle/knee and knee/hip was greater ($p<0.05$) for IL compared to NIL (+23% and +40% respectively). In conclusion, the jumping strategy assessed through the analysis of inter-joint coordination was still affected in ACL-R patients, which may be a cause of re-injury.

Keywords: knee; continuous relative phase; rehabilitation; injury; 2D kinematics

Introduction

Anterior cruciate ligament (ACL) injury is one of the most common knee injuries in sports activities [16]. Most of the injured people undergo ACL reconstruction (ACL-R), following by a long rehabilitation. In addition, the return to physical activity is not satisfying since only 63% of the patients return to their pre-injury sporting level [1] and most of them have a risk re-injury [37,43,48,51,59]. This may be explained by the greater asymmetries observed during multi-joint tasks and jumping activities between the injured leg (IL) and non-injured leg (NIL) for ACL-R patients in comparison to healthy people [12,23,38,44,60]. For instance, during the push-off phase of a single-leg jump, some studies observed a smaller range of motion of the knee [38], ankle and hip [39] for IL in comparison to NIL. From a mechanical point of view a lower ankle [40] and knee joint power [38] was observed for IL in comparison to NIL. Although these studies gave insights about the lower limb asymmetries after ACL-R, each joint was assessed independently. However, to the best of our knowledge no study has assessed how the coordination between the lower limb joints may be affected.

To investigate neuromuscular control through inter-joint coordination after ACL-R may be of great interest for clinicians. Indeed an altered neuromuscular control has been shown to be a predictor of a second ACL injury [44]. In addition the ACL plays a major function in lower limb coordination. Indeed the ACL is not a simple mechanical structure that enables to stabilize the knee [21]. The ACL is composed of mechanoreceptors that provide feedback to the central nervous system about the position and the velocity of the joints via the γ–muscle spindle system. Consequently it may be assumed that ACL injury alter the feedback properties of the ACL and therefore alter inter-joint coordination during dynamic movements. This alteration has been observed in gait [36] and postural activities [34]. Nevertheless, to the best of our knowledge no study assessed the effect of ACL-R on inter-joint coordination during dynamic movement such as vertical single-leg jump. Although ACL injury does not often occurs during the push-off phase of vertical jumping, the investigation of the push-off during maximal single leg jump makes it possible to compare a standardized multi-joint movement (i.e. only one aim which is jumping as high as possible) between ACL-R and healthy people. In addition, vertical jumping is an important factor of performance in many sports (e.g. basketball, volleyball, soccer) that requires a specific inter-joint coordination during the push-off in order to maximize vertical jump height [9]. Consequently investigating the push-off phase of a single leg jump may be relevant to assess if inter-joint coordination is altered in athletes after ACL-R.

Joint coordination in vertical jumping may be assessed with different methods such as electromyography [47], sequencing of a segmental movements [46] and continuous relative phase (CRP) [13,14,22,30]. The latter is based on a dynamical system approach [24,25,49] and enables to reduce the complexity of the system composed initially of four degrees of freedom (i.e distal and proximal angle and velocities) to only one degree of freedom [13,25]. CRP has been used to evaluate inter-articular/segmental coordination in many tasks such as gait [57], running [27], swimming [50], and jumping [13,14,22,30] in healthy or patients with ACL-R [34,36]. In addition the value of the CRP enables to determine the leading segment or joint [25], information that may be useful in vertical jumping since a constant proximo-distal joint extension is usually observed in healthy people [9]. Finally the variability of CRP may be also relevant because this variable has been related to injury risk. Nevertheless two opposite conclusions have been made, on one hand a high variability may reduce the risk of chronic injury because the mechanical loads would not be applied to one single body area during repetitive movements [4,25]. On the other hand, a high variability may correspond to an instable pattern which may result from an alteration of the proprioceptive functions and therefore increase the risk of injury [34].

Consequently the purpose of this study was to evaluate the inter-joint coordination asymmetry between IL and NIL in patients after ACL-R during single-leg vertical jumping in comparison to a healthy population. To that aim CRP was compared between IL and NIL of ACL-R patients and between the dominant (DL) and non-dominant leg (NDL) of healthy people. According to the results observed in gait and postural activities, it was hypothesized that the asymmetry of the CRP and its variability were greater in ACL-R patients in comparison to the healthy group.

Material & Methods

Participants

The asymmetry of the lower-limb kinematics after ACL-R being gender dependent [17], only one type of population (i.e. males) was enrolled in this study in order to improve the homogeneity of the participants. Two groups of male athletes volunteered to participate in this study: patients who had undergone ACL-R and healthy individuals. Their characteristics are presented in Table 1. The participants accepted and signed an informed consent being previously approved by the Ethics Committee of the University. Finally, the study was conducted in accordance with recognised ethical standards and national/international laws [26].

In line with previous studies [36,38,40], the first group included 12 males who had undergone unilateral bone–patellar–tendon–bone autograft ACL-R after isolated ACL injury. The surgeries were performed by two experienced surgeons from the same orthopaedic department. The patients performed similar rehabilitation exercises in term of number of training sessions (35 ± 5) and contents (i.e. strengthening, functional training, electrotherapy and neuromuscular re-education) based on the recommendations of van Grinsven [56]. Patients took part in the experiment from five to nine months after surgery when they were identified as able to return to sports activities according to criteria such as no pain during daily life activities and rehabilitation sessions, no episode of giving-way, full ROM at the knee joint, and being in the last stage of the rehabilitation program (Phase 4) [56]. In addition the patients stated that they had no recent history of injury or surgery to the NIL and to the IL (since the ACL reconstruction). Just prior to the experiment patients' subjective functional recovery was evaluated by the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form [28,31]. An experimented physiotherapist was present to help the patient to fill the IKDC form. Pre-injury and current activity levels were determined from the scale of Tegner et al. [54]. Finally prior to injury, all patients practiced sports two to three times a week (soccer, basketball, or handball) and their ACL injury occurred during sports activities.

The second group included 12 healthy males with no prior history of knee and lower limb injury. They participated in sports two to three times a week (soccer, basketball or handball). There was no significant difference in age, height, weight, and pre-injury Tegner activity level score between the healthy and the ACL-R groups.

"Insert table 1 near here"

Instrumentation and data collection

According to previous studies analysing vertical jumping [6,40], reflective markers (Ø 1cm) were located by the same experimenter on the left and right fifth metatarsophalangeal, lateral malleolus, lateral femoral condyle, great trochanter, and acromion. The ground reaction force was recorded for each single leg jump with a force plate sampled at 1000 Hz (AMTI, model OR6-7-2000, Watertown, Massachusetts, USA). In addition the single leg jumps were filmed in the sagittal plane with a camera (Ueye, IDS UI-2220SE-M-GL; IDS Imaging Development Systems GmbH, Obersulm, Germany) operating at 100 Hz .The optical axis of the camera was perpendicular to the plane of motion and the lens was located at 4 m from the participant.

Experimental procedure

Prior to the test the participants performed a 15-min warm up including single leg squat jumps with arms akimbo. During the warm-up, the participants also chose their preferred initial posture for each leg, which was kept constant for all the trials during the testing session.

The test consisted of a random sequence of three barefoot single leg squat jumps with the right and left leg with arms akimbo. The squat jump was studied because it enabled to investigate inter-joint coordination only during the ascending phase of the push-off without the effect of the descending phase. In order to determine the start of the push-off (see section data treatment) the participants had to keep their initial posture during 1 second before starting the push-off. In addition, a marker was placed on a yardstick in front of the participant at the eye level and another one was placed on another yardstick at the hip level [7]. This procedure ensured that the participant had a similar initial posture all through the trials (may be different between the left and right leg). Then the participants were asked to jump as high as possible without any countermovement which was visually controlled using the vertical ground reaction force signal. When a countermovement was identified, the jump was cancelled and the participant had to perform another single leg squat jump in order to obtain a total of six valid jumps (three for each leg). Finally, the participants had to stand upright during two seconds (left and right profile) in order to record the position of the reflective markers during a static position.

Data treatment

For each trial, mean and standard deviation of the vertical ground reaction force (R_z) were determined over the first second in which the participants held the initial equilibrium posture. The beginning of the push-off corresponded to the instant, when after the first second, R_z increased more than two standard deviations above body weight [8]. Then the end of the push-off was used to synchronize the kinematic and kinetic signals. It corresponded, respectively, to the last frame when the feet were in contact with the ground and the last time value before R_z dropped to zero. Finally, marker positions were digitized, frame by frame, with an auto-recognition software (the Loco®; Museum National d'Histoire Naturelle, Paris, France) [7,41] and smoothed with a zero-lag fourth order low-pass Butterworth filter with a cut-off frequency of 10 Hz.

2-D kinematics and relative phase

Vertical jump height (VJH) was obtained from R_z as explained by Eq.1 and Eq.2:

$$a_z(t) = -g + \frac{R_z(t)}{m} \Leftrightarrow v_z(t) = \int_{t_i}^{t_{i+1}} a_z d(t) \quad \text{Eq.1}$$

$$VJH = \frac{v_z(takeoff)^2}{2g}, \quad \text{Eq.2}$$

with a_z *and* v_z respectively the vertical acceleration and velocity of the body mass center, *t* denotes the time for each sample (*i*).

The kinematic model, implemented from the position of the markers digitized during the static posture, was composed of four segments: left or right (depending of the limb analyzed) foot, shank, thigh and "head-arm-trunk". Two-dimensional segmental joint angles were obtained using a global optimization algorithm in order to minimize soft tissue artefact [5]. The global optimization consisted in finding the segmental angles by minimizing the sum of the quadratic difference between the measured and reconstructed marker positions. Thereafter ankle, knee and hip joint angles were calculated from segmental angles (Figure 1).

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The continuous relative phase (CRP) was calculated between each joint according to Hamill et al. [25] in order to assess the inter-joint coordination during the single leg squat jumps. The phase plot was obtained for each joint (j) by representing the normalized angular velocity $(\dot{\theta})$ with respect to its corresponding normalized angle (θ) according to Eq.3 and Eq.4:

$$\theta_j^{norm} = \frac{2 * [\theta_j - min(\theta_j)]}{max(\theta_j) - min(\theta_j)} \quad \text{Eq. 3}$$

$$\dot{\theta}_j^{norm} = \frac{\dot{\theta}_j}{max[max(\dot{\theta}_j), \max(-\dot{\theta}_j)]} \quad \text{Eq. 4}$$

Then the phase angle (φ) ranging between 0 and 180° was calculated as the four-quadrant arctangent angle formed between the normalized angle velocity and angle (Eq.5). Finally CRP was calculated between each joint by the difference between the phase angles (Eq.6)

$$\varphi_j = \tan^{-1}(\dot{\theta}_j^{norm} / \theta_j^{norm}) \quad \text{Eq. 5}$$

$$CRP_{a-k} = \varphi_{ankle} - \varphi_{knee}$$
$$CRP_{k-h} = \varphi_{knee} - \varphi_{hip} \quad \text{Eq. 6}$$
$$CRP_{a-h} = \varphi_{ankle} - \varphi_{hip}$$

Consequently CRP ranged between -180 and 180°. A CRP close to 0° meant that the two joints evolve in phase, while a CRP close to 180° or -180° corresponded to an anti-phase. Finally, a negative value meant that the proximal joint was leading the distal joint [25].

Analyzed variables

In order to determine the dominant leg of the healthy subject, the average vertical jump height (between the 3 jumps) was calculated for each leg. Then the dominant leg corresponded to the leg enabling the highest vertical jump height. Concerning the ACL-R group the dominant leg corresponded to NIL [39].

The first variable analyzed was the mean CRP. To obtain this value, the CRP curves of the three trials were averaged, separately for each joint coupling (ankle/knee, knee/hip and ankle/hip) and each leg (NL and NIL). Then the mean of the averaged curve corresponded to the mean CRP. The second variable analyzed was the variability of the relative phase [13,14]. To compute the latter, the standard deviation of the CRP curves between the three trials was calculated, separately for each joint coupling and each leg. Then the mean value of the standard deviation curve corresponded to the variability of the relative phase.

Statistics

Linear mixed-models were used to evaluate the effect of the group (healthy/ACL-R) and the leg (DL/NDL or NIL/IL) on the means of the vertical jump height, CRP and CRP variability for each joint coupling (ankle/knee, knee/hip and ankle/hip). Linear mixed-model is an alternative method of the ANOVA that may be more advantageous especially with categorical data [3]. The interaction between the group and the leg were entered as fixed effect, while the participants were entered as random intercept. The p values were obtained by likelihood ratio tests of full model against the model without the effect in question [45,58]. The level of significance was set at $p<0.05$. The linearity, homoscedasticity and normality of the residuals were graphically controlled. Finally when an interaction effect was revealed by the linear mixed-model, each group was treated individually and the effect of the leg (DL/NDL or NIL/IL) was tested using Holm-Bonferroni-corrected paired-samples t-tests. In addition the effect size (ES) was calculated for the paired-samples t-tests using the Cohen's d coefficient. All analyses were executed using R software (R 3.2, RCore Team 2014, package *lme4*).

Results

The linear mixed-models revealed an interaction effect between the group and the leg on vertical jump height ($\chi^2(6)=12.07$, $p<0.001$). This result meant that the discrepancy between the legs (DL/NDL or NIL/IL) was different between the groups. Indeed, the post-hoc analyses showed no significant difference between the DL and NDL for the healthy population (0.184±0.088 vs. 0.180±0.083 m, $p=0.31$) while vertical jump height was significantly smaller for the IL in comparison to the NIL of the ACL-R patients (0.062±0.033 vs. 0.111±0.042 m; $p<0.001$; ES=1.24).

The CRP of each joint coupling and for each group was presented in figure 2. The linear mixed-models revealed an interaction effect between the group and the leg on the mean CRP for the couplings ankle/knee ($\chi^2(6)=5.26$, $p<0.05$) and ankle/hip ($\chi^2(6)=4.42$, $p<0.05$), while no effect of the leg or group was observed for the coupling knee/hip. These results meant that the difference between the legs (DL/NDL or NIL/IL) was different between the groups for the couplings ankle/knee and knee/hip. Indeed, the post-hoc analyses revealed that the mean CRP of each joint coupling was similar between DL and NDL for the healthy group. By contrast the post-hoc analyses showed that the mean CRP of the coupling ankle/knee and ankle/hip was significantly smaller ($p<0.01$; ES(ankle/knee)=0.80;

ES(ankle/hip)=0.57) for the IL in comparison to the NIL of the ACL-R patients (on average -30% and -22% respectively) (Table 2).

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The CRP variability for each joint coupling and group was presented in figure 3. The linear mixed-models revealed an interaction effect between the group and the leg on the CRP variability for the couplings ankle/knee ($\chi^2(6)=4.36$, $p<0.05$) and knee/hip ($\chi^2(6)=4.40$, $p<0.05$), while only a main effect of the leg was observed for the coupling ankle/hip ($\chi^2(4)=5.05$, $p<0.05$). These results meant, firstly that the difference between the legs (DL/NDL or NIL/IL) was not dependent on the group for the coupling ankle/hip. On the opposite, for the coupling ankle/knee and knee/hip, the difference between the legs (DL/NDL or NIL/IL) was different between the groups. The post-hoc analyses revealed that CRP variability of these joint couplings was similar between DL and NDL for the healthy group. By contrast the CRP variability of the couplings ankle/knee and knee/hip was significantly greater ($p<0.05$; ES(ankle/knee)=0.66; ES(knee/hip)=0.78) for IL than for NIL (on average +23% and +40% respectively) (Table 3).

"Insert figure 3 near here"

"Insert table 3 near here"

Discussion

The main findings of this study support our hypothesis that greater asymmetries in inter-joint coordination were present in ACL-R group in comparison to a healthy population. These greater asymmetries were observed both for the mean CRP and the CRP variability.

Inter-joint coordination

The greater inter-joint coordination asymmetries measured in ACL-R group during the single leg jump coincides with other studies having observed an alteration of inter-limb coordination in ACL-R patients during their locomotion [10,11,15,19,36] or postural activities [34]. Nevertheless, our study is the first one having shown the alteration of inter-joint coordination during a dynamic movement such as single-leg jumping which is a key factor of performance in many sports activities such as soccer [2], basketball [53] and volleyball [20]. Both for healthy and ACL-R group, and whatever the leg (DL/NDL or NIL/IL) the mean CRP was negative for each joint coupling, meaning that the proximal joint was leading the distal one [25]. This result confirms the natural proximo-distal coordination observed in vertical jumping [9]. However, although the ACL-R group did not change the global pattern (i.e. proximo-distal coordination), we observed some discrepancies between IL and NIL, while no asymmetry was observed in healthy patients. The smaller mean CRP in IL for the couplings ankle/knee and ankle/hip meant that the hip and knee extensions were more ahead of the ankle extension in comparison to NIL.

The second main finding was that the CRP variability for the couplings ankle/knee and knee/hip was greater for IL in comparison to NIL while no asymmetry was observed for the healthy group. The CRP variability corresponds to the capacity of the neuromuscular system to reproduce a stable pattern of coordination [33,55]. Consequently our results showed that the coordination between the knee and hip or between the knee and ankle was less stable for IL in comparison to NIL. This result may correspond to an incomplete motor pattern recovery or neuromuscular deficit explaining a decrease in lower limb stability [34]. The knee stability during sports is mainly ensured by the coordinated co-activation of the adjacent muscles [52]. It has been theorized that a great variance in these co-activation strategies is related to the risk of ACL rupture [18]. Consequently, it may be hypothesized that the smaller lower-limb stability observed in our participants may increase their risk of ACL re-injury.

The asymmetry of inter-joint coordination after ACL-R may be explained by several parameters. Although speculative, it may be hypothesized that ACL-R leads to impair the sensory information provided by the reconstructed knee [21,32]. Consequently, less feedback about the joint position and velocity may be given to central nervous system and therefore alter inter-joint coordination. Another hypothesis was that ACL-R tended to affect non-homogenously joint force production of IL [40] and consequently modify lower limb joint coordination. Finally the knee is located in the middle of the lower limb chain, consequently an alteration of its function may lead to affect the energy transfer from the hip to the ground [42]. Nevertheless further studies are needed to confirm these hypotheses.

The last finding was that the ACL-R group jumped less high with the IL in comparison to the NIL. This result has already been observed in previous studies [12,40]. Nevertheless, the asymmetry in vertical single-leg jump was explained by a deficit in mechanical jump work produced by IL in comparison to NIL [39]. However, an optimal proximo-distal inter-joint coordination is also necessary to achieve a maximal vertical jump

[9]. Consequently it may be hypothesized that the alteration of inter-joint coordination is one of the factors explaining a lower vertical jump height for IL of the ACL-R group.

Limitation

The first limitation of this study was that only males with bone-patellar tendon-bone graft were evaluated. Therefore our results cannot be generalized to females or patients having undergone ACL-R with other techniques (e.g. hamstrings graft). The second limitation was that no information was provided about the knee joint flexion/extension torque of IL and NIL. The asymmetry in inter-joint coordination may also be caused by a weakness of the IL muscles. Consequently further study is needed to assess if inter-joint coordination asymmetry is correlated to knee joint torque deficit. The third limitation was about the normalization used for the computation of the CRP. Indeed Kurz et al. [35] pointed out that the method of normalization of the angle and angular velocity may affect the results of CRP. However, we calculated the CRP with both the method of Hammill et al. [25] and Kurz et al. [35] and always found the same significant difference between the group and the leg. Consequently we decided to present a method widely used in the literature investigating vertical jumping [13,14,22].

Conclusion

Our study pointed that 7.3 months after ACL surgery, the lower-limb coordination of our male patients was still affected during a maximal vertical single-leg jump. The contralateral asymmetry in CRP and CRP variability observed in our male patients may correspond to an impairment of the neuromuscular control. Many studies have shown that neuromuscular training based on multi-joint movements improves motor control, decreases asymmetries and prevents lower limb injuries [29]. Thus, in order to improve motor control, physiotherapists should incorporate in their rehabilitation protocols multi-joint and multi-planar movements of progressively greater speed and difficulty [18]. They should also combine bilateral training to decrease leg-to-leg asymmetries being a predictor of second ACL injury to the contralateral or ipsilateral side [44]. It can be suggested to include exercises like lunge and tuck jump exercises in rehabilitation after ACL-R may therefore decrease CRP asymmetry and variability in male athletes. Nevertheless further studies are needed to assess the real effect of such a program training on lower-limb CRP.

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Table 1. Descriptive data for the subjects in healthy and ACL-R groups (mean ± standard deviation and range)

		Healthy	ACL-R
Age (years)		25.5±4.5	23.9±5.8
Height (m)		1.76±0.09	1.78±0.06
Weight (kg)		72.9±13.6	79.6±8.1
Time to surgery (months)		NA	3.2 (range: 0.7-5.7)
Time since surgery (months)		NA	7.3 (range: 5-9)
Tegner activity level score (0–10)	Pre-injured	NA	5.8 (range: 5-10)
	Experimentation	6.7 (range: 5-10)	4.3 (range: 4-5)
IKDC Subjective Knee Evaluation (0–100)		NA	75.9±13.6

Table 2. Mean ± Standard deviation of the mean relative phase with respect to the group and leg.

	Healthy group			ACL-R group		
	DL	NDL	95% CI (DL-NDL)	NIL	IL	95% CI (NIL-IL)
a-k	-4.91±1.01	-5.24±1.72	-0.32 – 0.98	-5.95±1.49	-7.75±2.82#	0.57 – 3.03
k-h	-8.16±4.18	-7.38±3.49	-3.42 – 1.87	-5.50±3.00	-6.26±4.41	-0.67 – 2.19
a-h	-13.07±4.08	-12.63±2.81	-3.04 – 2.14	-11.45±3.39	-14.02±5.21#	0.78 – 4.34

a-k: joint coupling ankle/knee; k-h: joint coupling knee/hip, a-h: joint coupling ankle/hip; DL: dominant leg; NDL: non dominant leg; NIL: non injured leg; IL: injured leg; CI: confidence interval; # means a significant difference ($p<0.05$) between DL and NDL or between NIL and IL.

Table 3. Mean ± Standard deviation of the continuous relative phase variability with respect to the group and leg.

	Healthy group			ACL-R group		
	DL	NDL	95% CI (DL-NDL)	NIL	IL	95% CI (NIL-IL)
a-k	1.35±0.72	1.13±0.30	-0.26 – 0.70	1.42±0.50	1.74±0.43#	-0.62 – -0.02
k-h	2.34±1.00	2.63±0.93	-1.14 – 0.33	1.74±0.65	2.44±1.09#	-1.21 – -0.21
a-h	2.24±0.90	2.85±1.00	-1.02 – 0.44	2.51±0.79	3.04±1.17	-1.15 – 0.09

a-k: joint coupling ankle/knee; k-h: joint coupling knee/hip, a-h: joint coupling ankle/hip; DL: dominant leg; NDL: non dominant leg; NIL: non injured leg; IL: injured leg; CI: confidence interval; # means significant difference ($p<0.05$) between DL and NDL or between NIL and IL.

Figure 1 - Set up of the experimental procedure

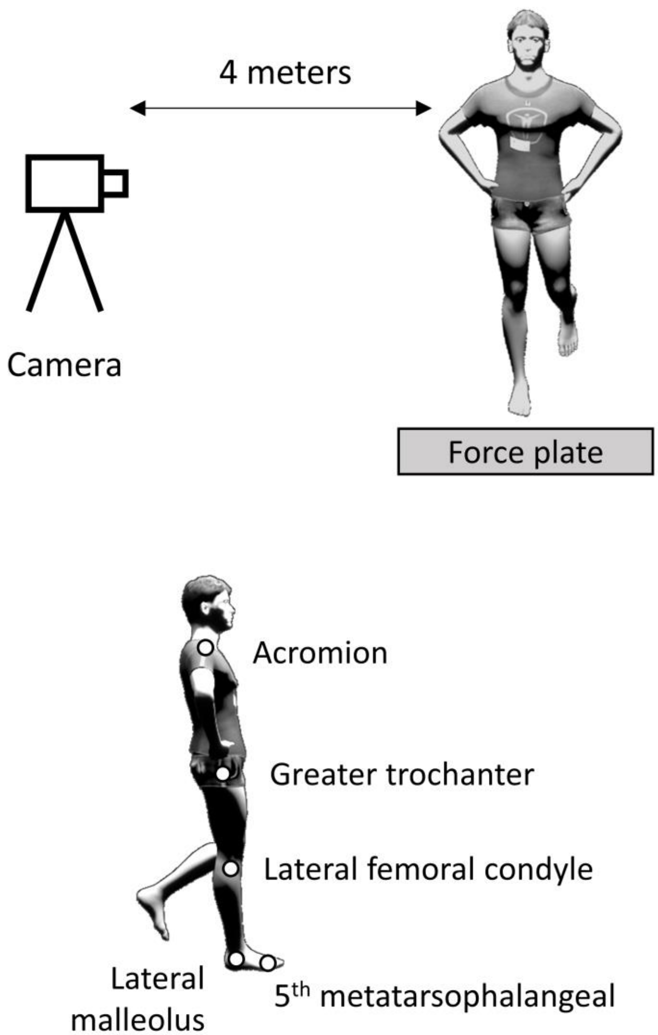

Figure 2 - Stick diagram representing the subject by four rigid segments and three articular joints

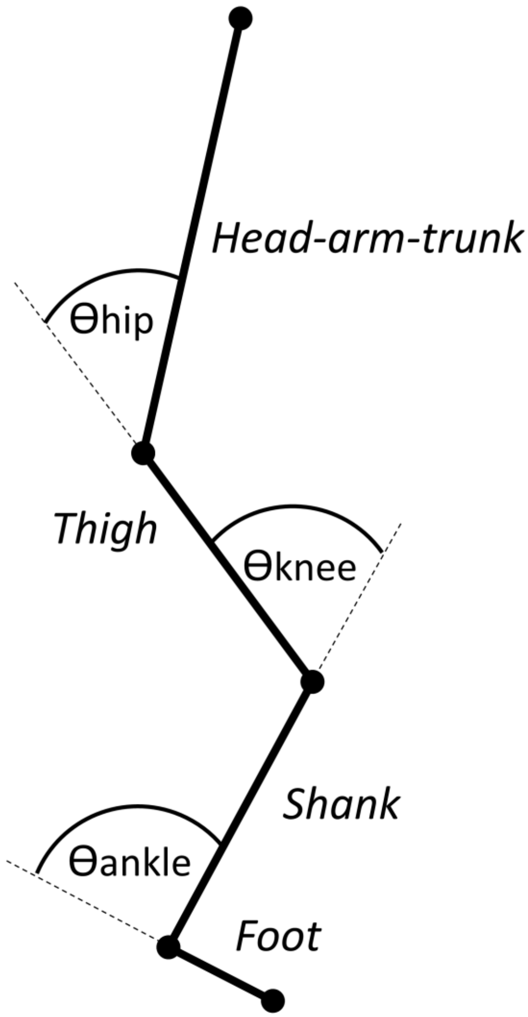

Figure 3 - Time history of the continuous relative phase (mean ± SD corresponding to the solid line and area) for the average ACL-R (top) and healthy (down) groups. The couplings ankle/knee (a-k), knee/hip (k-h) and ankle/hip (a-h) are represented. 0% corresponded to the beginning of the push-off and 100% to take-off.

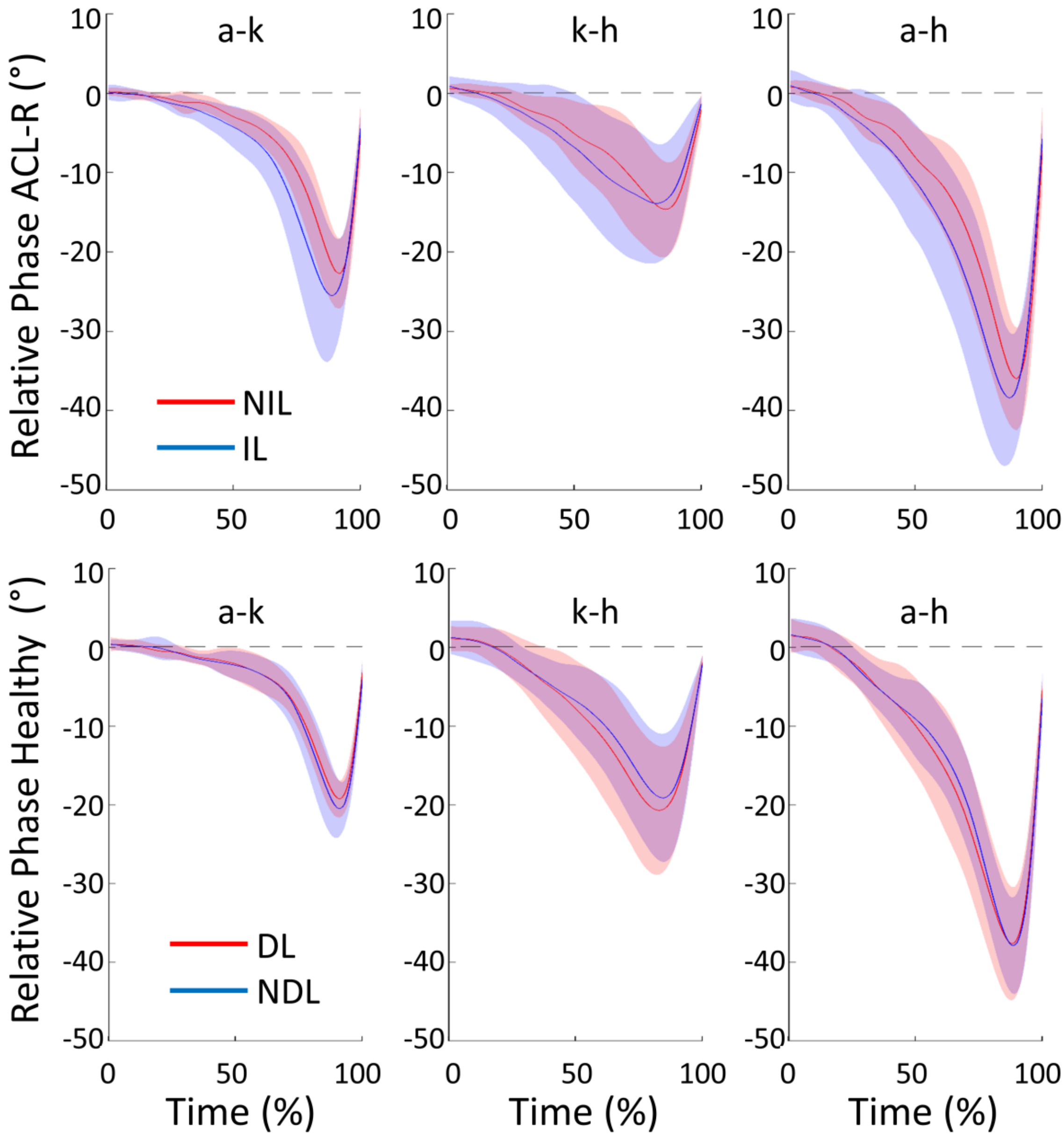

Figure 4 - Time history of the continuous relative phase variability (mean ± SD corresponding to the solid line and area) for the average ACL-R (top) and healthy (down) groups. The couplings ankle/knee (a-k), knee/hip (k-h) and ankle/hip (a-h) are represented. 0% corresponded to the beginning of the push-off and 100% to take-off.