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BIOMECHANICAL ANALYSIS OF TWO METHODS OF DESCENDING STAIRS

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ABSTRACT

The activity of descending stairs increases loading at the joints of the lower extremities (Andriacchi et al., 1980) as compared to walking (McFadyen and Winter, 1988), which may cause certain discomfort and or difficulties in completing the task. This study compared and contrasted the kinematics and kinetics of forward and backward stair descent to Winter's level walking (1991). We compared the support moments and moment powers of the lower limb joints while descending stairs and secondly, performed an analysis of the position of the foot on the step (ground reaction forces) to determine which method was more likely to reduce the risk of slipping. Ten subjects (6 men and 4 women) with diverse heights (1.65 m ± 3 cm, 1.73 m ± 3 cm, and 1.80 m ± 3 cm) and between the ages of 20 and 35 were studied. Sagittal plane kinematics, ground reaction and forces were collected and moments calculated through an inverse dynamics approach. Kinematics and kinetics for forward and backward stair descent were contrasted to level walking (Winter, 1991). The ratio of stance/swing phase changed from Winter's 60:40 for normal level walking to between 65:35 and 70:30 for stair descent. Larger double peak support moments with reduced ankle plantar flexor and increased knee extensor moments were found. The hip moments were relatively small and highly variable. The horizontal distance of the ground reaction force from the edge of the step showed a significant increase ($P<0.001$) for backward stair descent versus forward stair descent. Average stair descent cycle duration increased when descending backward (1.349 s) compared to forwards (1.134 s) ($P<0.03$). There was a significantly reduced peak knee extensor eccentric power ($P=0.005$) with backwards descent. These results demonstrate that stair descent (forward and backward) required higher moments

at the knee than level walking but backward descent demanded less peak knee moment and eccentric power than forward descent. Overall, the use of a backward approach, offer an alternative for people unable to access stairs in the forward fashion.

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Chapter 1

INTRODUCTION

The ability to do everyday activities is often taken for granted. Walking to the store, sitting in a chair, or descending a flight of stairs are activities that can be done by many able bodied individuals with ease. Stairs are an integral part of our societal architecture and as a result, the ability to manage stairs in a safe and independent fashion is an important activity of daily mobility. Falls on stairs is a leading cause of accidental deaths and of morbidity (Simoneau et al., 1991) and has therefore attracted much focus from the perspective of injury prevention (Nahorniak et al., 1999; Andriacchi et al., 1980). For the physically injured (Durand et al., 1993), people physically (Simoneau et al., 1991) and cognitively impaired (Sparrow et al., 1998) and the elderly (Startzell et al., 2000; Wyatt et al., 1999) these tasks can be strenuous, painful, dangerous and sometimes impossible. Descending stairs is a task that increases loading of the joints of the lower extremities (Andriacchi et al., 1980) as compared to level walking (McFadyen and Winter, 1988), which may cause both discomfort and difficulty in completing the task of stair descent. Furthermore, the foot position may cause an indirect loss of balance and stability while negotiating stairs (Simoneau et al., 1991). These differences may result in increasing or decreasing the chances of experiencing a fall while descending stairs (Simoneau et al., 1991).

Objectives of the study

The general aim of this study was to compare and contrast the kinematics and kinetics of forward and backward stair descent as a means of assessing the difference in the support moments and moment powers for each method. The specific objectives were to compare the support moments, joint moments and moment powers of the lower limb joints while descending stairs in both forwards and backward directions and to compare the average descent time of forward and backward descent. Finally, an analysis of the locations of the ground reaction forces was examined to determine which method was more likely to reduce the risk of an accident.

Justification for the proposed research project

In our modern society stair descent represents a hazard. The causes vary and are under research by investigators throughout many countries. Because of the complex interaction of external (Andriacchi et al., 1980, Loy and Veloshin, 1991, Livingston et al., 1991, Simoneau et al., 1991) and internal (Sheehy et al., 1998, Townsend et al., 1978, Nahorniak et al., 1999, Startzell et al., 2000) factors contributing to falls it is hardly possible to study the problem using a single approach or a single research method. The present study applies biomechanical information to investigate factors associated with stair descent.

The purpose of this study was to compare two different methods of descending stairs (forwards and backwards). In doing this, a comparison was made concerning the moments of the lower limb joints while descending stairs in both the forwards and backwards directions with Winter's level walking (1991). This part of the study made a simple comparison of what the lower extremity joints were experiencing under the different conditions. Because little has been done in the literature with this approach, the hope was to determine if descending stairs backwards decreased the peak moments and forces experienced by the lower extremity joints.

In the final analysis, even a small change using a backward descent may affect the relative risk of slipping off the edge (Andriacchi et al., 1980) or collapsing. Descending stairs is a potential risk of serious injury for many groups within the population (Startzell et al., 2000; Simoneau et al., 1991; Wyatt et al., 1999). Thus, it becomes important to invest time in researching possible scenarios that may reduce accidents.

Limitations

There were two reasons for using a sagittal planar motion analysis for this study. Firstly, the contribution of internal and external rotation to overall gait was documented as being minimal. In a straightforward study by Andriacchi et al., (1980), using 3-D kinematics, it was concluded, "the internal and external moments were quite low and variable (less than twenty newton metres)" (Andriacchi et al., 62-A: 756, 1980). Similarly, in a stair study done by Kirkwood et al., (1999) it was concluded that the external rotation moments obtained during stair descent, about the knee and hip, were comparable to those obtained during level walking. It is important to note that these studies looked at data of stair climbing gait from those individuals without pathologies in their gait. In fact, the study performed by Kirkwood et al., (1999) used a sample of elderly adults aged 55 years and older without gait pathologies. Because the present study used a sample of young and healthy adults, the planar motion analysis data were all that was required to get baseline data about peak moments experienced at the lower extremity joints. We selected subjects' whose age ranged between 20 and 35 and with no previously diagnosed lower limb injury.

Assumptions

It was assumed that all segments of the lower extremities being studied were rigid bodies. In other words, the centre of mass and radius of gyration for each segment (i.e., foot, lower leg, upper leg, and torso) remained constant during motion. This assumption is considered accepted practice (Winter, 1991).

Each subject was required to wear close fitting dark clothing with body segment markers placed on the body. These markers were used when digitizing the body segment movements. Because the clothing was form fitting, the movement of these markers was assumed to be minimal.

Chapter 2

REVIEW OF LITERATURE

The application of an interdisciplinary approach to solve problems faced by people with injuries, physically challenged and the elderly create a better perspective to view and narrow down problems and possible solutions. The study of human gait has been a long process. To date, a major focus of gait analysis has been spent collecting data (kinematics, kinetic, and EMG) to develop mathematical models for level walking gait and inclined surfaces (McFadyen and Winter, 1988). McFadyen and Winter's study (1988) has set the standard on how to study the mechanics of stair ascent and descent. In this review of literature we will review studies that investigated the area of gait and stair ascent and descent to explain where the gaps in research still exist.

The introduction of computers in biomechanics has made gait analysis easier to focus on the ascending and descending stairs (Andriacchi and Alexander, 2000). With computers, we were able to capture gait and create mathematical models. Duncan et al., (1997) and Townsend and Tsai (1976) created a mathematical model for stair climbing and descending to enable the calculation of joint powers and basic stair descent characteristics.

Studies have used kinematics and kinetics to collect data to establish basic information about the biomechanical effects of stair climbing on the body. We will examine them individually and then will follow specific examples of how kinematic and kinetic data collection methods have advanced what we know about stair climbing

Gait Characteristics:

Winter (1980) has identify two gait phases: stance phase and the swing phase (see Figure 1, Townsend et al., 1978). The stance phase, during level walking has been experimentally shown to take up the first 60% (Andriacchi and Alexander, 2000) of the overall gait cycle. This phase include two double support (DS) phases or double leg support (DLS). They contribute to 20% (10% each) of the overall walking cycle.

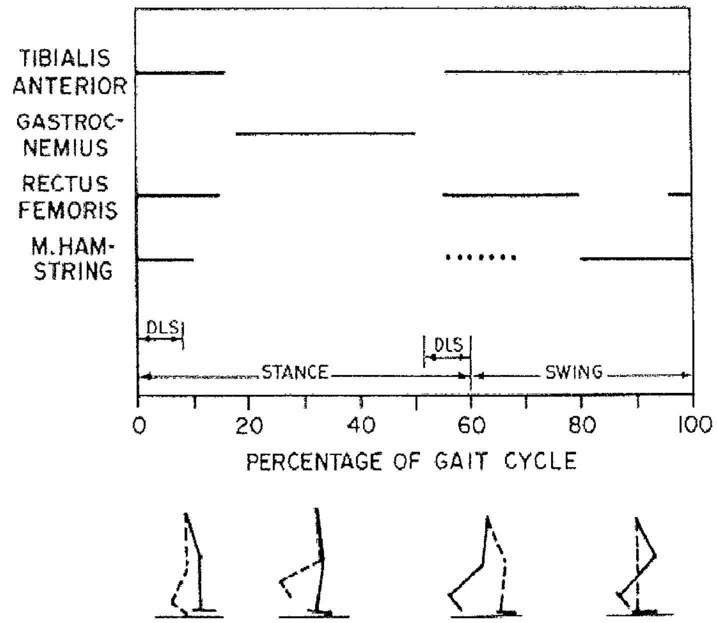


Figure 1: Normalized gait pattern for level walking of 19 subjects. The figure shows the time during which a muscle is active. Gait pattern normalized to percentage of cycle time and each gait cycle begins with contact of the right foot.

Note: Reference, Townsend et al., (1978)

In the case of walking down stairs, Andriacchi et al. (1980) used, like Winter (1980), the same two phases for describing gait. However, the percentage of time spent on each phase differed from that of level walking (Townsend et al., 1978). These are depicted in Figure 2, which illustrates the normalized gait pattern from research also done by Townsend et al. (1978).

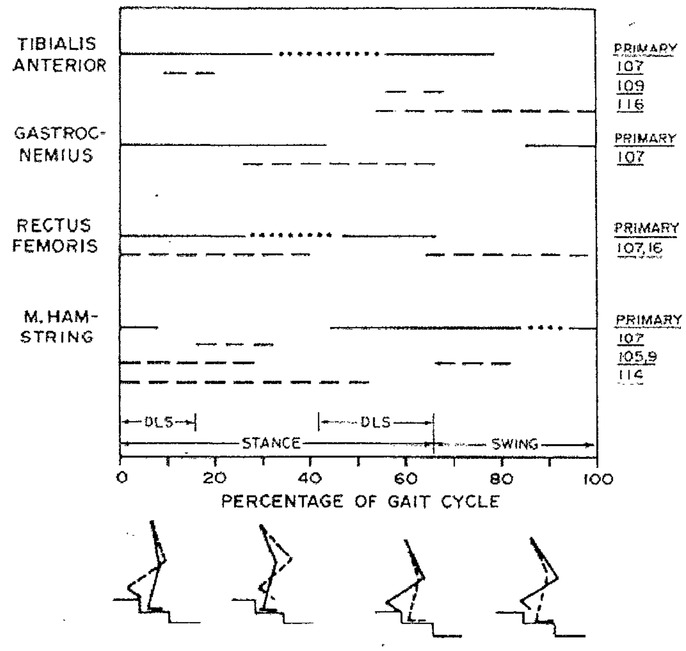


Figure 2: Normalized gait pattern for stair descent of 19 subjects. The figure shows the time during which a muscle is active. Gait pattern normalized to percentage of cycle time and each gait cycle begins with contact of the right foot

Note: Reference, Townsend et al., (1978)

In performing any stair study we have to identify frequency variation in gait patterns. If the gait frequency chosen for the study is too fast, there may be a reduction of time for this double support (DS) or double leg support (DLS) phase consequently, chances of hazard might increase. Furthermore, changes in temporal pattern between populations (Simoneau et al., 1991) or methods of stair descent can be a determinant for pathologies or the potential for falls.

Kinematics:

The use of kinematics in biomechanical studies of gait has played an important role in understanding the breaking down (in parts or fragments) of human locomotion to determine characteristics of gait. Among the information learned by kinematics studies are gait patterns, gait cycle characteristics, and joint velocities and angles. In relation to be effective in providing basic information about how humans ascend and descend stairs we have used the kinematics as a biomechanical assessment tool in step up/step down studies.

Livingston et al., (1991), and McCrory and Gilchrist (2000) looked at the biomechanical effects of changing stair dimensions on gait. Both of these studies used 2-D kinematics to analyze how different stair dimensions affect gait. In the study done by Livingston et al. (1991) stair climbing cycle duration, swing and stance phase duration, cadence, velocity, and knee joint angles were measured. They revealed how different stair dimensions affected both the stance (19% to 64%) and swing (36% to 81%) phases of gait in relation to the motor pattern each individual possessed (Joseph and Watson, 1967) and to their height (Livingston et al. 1991). They also concluded that the angle of the knee changed, more than the ankle and hip, to compensate for changes in stair rise and run values. Compensations by the hip when using steeper stair dimensions were also noted (Livingston et al., 1991).

A similar study performed by McCrory and Gilchrist (2000) used a steeper staircase as one of the variables. They confirmed an increased torque with an augmentation in the steepness of the stairs at both the knee and hip joints. Therefore, McCrory and Gilchrist

(2000) established that shallower stair conditions provide a better disposition to produce torque at the knee. Furthermore, a link was established between stair dimension and influence of the lower limb during stair ascent.

Loy and Voloshin (1991) used accelerometer data to analyze musculo skeletal shock waves during stair walking. The use of kinematics data (from accelerometers) determined that walking down a staircase induced shock waves with an amplitude of 130% of that observed in walking up stairs, and 250% of the shock waves experienced in level gait (Loy and Voloshin, 1991). These researchers realized that by combining force data from the use of force plates and accelerometers with kinematics data, power and moments about joints could be studied.

In summary, kinematics studies can be used to analyze gait characteristics. These characteristics include joint angles, joint angle velocity, range of motion, and cadence. Kinematics becomes a reference tool looking beyond what the eyes alone cannot perceive. In stair descent, the use of video may provide relevant information about positioning and motion of the leg reaching each step. Although kinematics data are useful for defining basic gait characteristics, they are inadequate to give more advanced information about what is actually happening in the joints of the lower limbs when descending stairs, and what are the contributions made by each joint's moment of force.

Kinetics:

Kinetics are concerned with the causes of motion and the action of forces (work, power, energy, impulse). It is essential to learn about the external forces acting on the body to determine the implications of physical stress experienced by humans both in sport, and during everyday activities. Kinetic data collection methods are very useful tools in the biomechanical analysis of gait. The forces imposed on the body can be quantified using accelerometers (Loy and Voloshin, 1991) and force plates to collect data (Winter, 1980). When using force plates, we collect ground reaction forces data, which reflect the net vertical and shear forces (Winter, 1991) acting on the surface of the platform. Then, using inverse dynamics in conjunction with a link segment model we can readily calculate the moments in the plane of progression (Winter, 1990).

Studies using inverse dynamics:

Up until recently, we have studied single variables. At times, however, these studies could have discovered even more information if they had combined one or more data collection methods. In fact, the trend in biomechanical research of gait has moved towards studying many dependent variables to gain even more specific information about human locomotion.

A combination of kinematics, kinetic, and EMG data to determine lower-limb mechanics during stair climbing was investigated by Andriacchi et al., (1980). More specifically, the displacement, forces, and moments of the ankle, hip, and knee were analyzed for both ascending and descending stairs. In this study, the joint angles were compared using kinematics data, for both ascending and descending stairs. After combining this information with force data, they found that the moments about the weight bearing joints of the lower limbs were greater for both ascending and descending stairs compared to level walking. Furthermore, the moments of the lower limbs were greater for descending compared to ascending (Andriacchi et al., 1980) and their results were confirmed by the study by McFadyen and Winter (1988). A combination of kinetic, kinematics, and EMG activity was also performed to reach their conclusions about the moments felt by the lower limb joints. This group also concluded that the muscle recruitment for stair climbing follows a basic mechanical pattern with the knee extensors being the greatest generator of energy and the ankle plantar flexors being the significant energy absorber during descent (McFadyen and Winter, 1988).

To determine moments about different joints, Costigan et al. (1998) used 3-D kinematics and an AMTI force plate to look at the knee joint moments. In their research, they used 35 students and input a subject specific knee model (AGAIT) to compute the forces and moments at the knee. They estimated the bone-on-bone contact forces and patellar joint reaction forces. With all the results obtained they establised a set of baseline data for knee moments.

Over the last 10 years, the biomechanics of stair climbing studies have used a combination of two or more of kinematics, kinetic and EMG assessments. Those combinations have contributed the most to truly understanding the differences among the joints of the lower limb experience in either ascending or descending stairs. Furthermore, similar methodologies were used as a tool in assessing functional capacity before and after surgeries, and in comparing normal groups to pathological groups. Overall, using a combination of methods to study gait and moments has been highly effective in stair climbing studies.

Stair Descent Studies:

From previous research, we know that the cyclic pattern of the lower limb during the task of stair descent is very similar to the cyclic pattern observed during level walking

(Livingston et al., 1991; McFadyen and Winter, 1988). The period of stance and swing were different. They are, in level walking at 60% stance and 40% swing (Mena et al., 1981; Joseph et Watson, 1967;Winter, 1984) whereas in stair descent they are, at 70% stance and 30% swing. The main differences were reflected by changes in the ranges of motion (Startzell et al., 2000; Andriacchi et al., 1980) of the different joints during gait and in the joint forces and moments. Some researchers observed about 83 degrees (Startzell et al., 2000; McFadyen and Winter, 1988; Shinno, 1971) of knee flexion when going down stairs. This is about 12 degree (Hoffman et al., 1977) more knee flexion than required during level walking (Andriacchi et al., 1980).

At the knee, the flexion moments while descending were the largest and necessitated a large force in the knee extensor muscle. Andriacchi et al., (1980) collected from 10 men with a mean age of 28 years, mean weight of 71 kg, and mean height of 179 cm. They collected mean maximal net flexion-extension moments of 112.5 N.m at hip, 146.6 N.m at the knee, and 107.5 N.m at ankle. The flexion moment at the knee was equal to 3 times larger than level walking. The maximum moment occurred at about 50% (Andriacchi et al., 1980) of the knee flexion whereas the level walking maximum occurred when leg was extended. The activity of descending stairs differs not only by the peak moments obtained but also by the difference in the muscle control. The descent was achieved through control by eccentric contraction (McFadyen and Winter, 1988) of the knee extensors and ankle plantar flexors. They were involved in the energy absorption during descent.

Thus, research has shown that differences exist between level walking and stairs descent not much showed the range of motion and moments required to complete the task of stair descent (Asher, 1977; Chen et al., 1991; Manning et al., 1997). High-risk groups like older people (Startzell et al., 2000; Wyatt et al., 1999; Daubney and Culham, 1999; Kirkwood et al., 1999; Manning et al., 1997; Chen et al., 1991; Asher, 1977), people with reduced vision (Startzell et al., 2000), people with orthosis (Brechter and Powers, 1999; Simoneau et al., 1991) or people with certain physical difficulties (Nahorniak et al., 1999; Durand et al., 1993) would benefit from deeper investigation on the stair descent. Minimal research focus has been put in looking at the relationship between stairs and falls (Wyatt et al., 1999) and the fact that certain groups of people could not access all stairways because of physical and psychological barriers.

In the next section we will review literature that relates to stair descent and slipping inducing a fall, and how a study using kinematics and kinetic data collection tools can be used to reduce chances of hazards on stairs.

The primary concern for people with limited visual acuity and range of motion or joint pain is not only ascending and descending stairs but also trying to avoid falls. Wyatt et al., (1999) in Scotland have looked at statistics on fatal falls down stairs, using a database between 1992 and 1997. During this period, 51 individuals died following falls down stairs. Of these 51 people, 84% or 43 people (Wyatt et al., 1999) died following falls down the stairs within their homes. Of these falls 17 of the 43 falls were individuals aged 65 years or more (Wyatt et al., 1999). The potential causes for these falls in the elderly were summarized as the following: simple trips and slips, impaired balance, lack of coordination and immobility, postural hypotension (particularly secondary to medication), arrhythmias, cerebro-vascular events and the affects of alcohol. Although this study was important in pointing out the severity and potential causes of these fatal falls, it is also important to look at what is occurring biomechanically so that education, intervention, and prevention can occur.

In public places, the largest proportion of fatal falls occurs while using stairways. Mcleans reported 236 stair's fatal falls in Canada. Of these falls, four out of five occur during stair descent (Simoneau et al., 1991). In reaction to this situation, Simoneau et al. (1991) wanted to determine the mechanism of falling. They looked at foot-stair spatial relationships during the mid-stair phase of stair descent. They also performed series of tests looking at the effects of various visual and environmental conditions on those variables. Their subject groups were women between the ages of 55 and 70. Under each condition, the dependent variables studied were cadence, foot clearance, and foot placement. It was discovered that stair descent was characterized by a small foot clearance ranging from 3.7 to 63.5 mm (Simoneau et al., 1991). These values, with a degradation of visual acuity, increased with the supporting foot located further back on the step and the cadence of step decreased (Simoneau et al., 1991). It was also mentioned in this study that the basic foot clearance range for the elderly populations were larger than those found in the same pilot study done on young, healthy subjects.

Sparrow et al. (1998), in a related study, focused on a comparison between normal males and females and a mentally challenged group for their stride length, relative speed, cadence, foot clearance and cycle duration. For each task they looked at foot clearance. The gait characteristics of mentally challenged individuals as they attempted to negotiate obstacles and clear stairs were analyzed. Although the study did not look at continuous stair descent, rather the descent of stepping off of a box, some interesting trends were determined. Namely, cycle duration for males was consistently longer for the mentally challenged group during stair ascent and descent. They concluded that individuals adjust the timing of foot placement to achieve the optimal foot position for safe clearance. The important information gained from this study was that gait characteristics do change when required to ascend or descend stairs.

The trend of stair studies has been to look at gait characteristics (cadence, range of motion, knee angle, etc.) during stair climbing, with the goal of determining differences in functional capacity. Some of these studies looked at gait before and after surgeries (Durand et al., 1993), as well as compared gait between normal groups and groups with pathologies (Heino et al., 2000; Hughes et al., 1999, 2000; Sparrow et al., 1998) or lower extremity braces (1999; Nahorniak et al., 1999). The similarity between all these studies is that gait was affected in one-way or the other.

Gait characteristics may be a measure of falling risk (Livingston et al., 1991; Manning et al., 1997; Startzell et al., 2000; Simoneau et al., 1991; Simoneau and Krebs, 2000; Wyatt et al., 1999). Measurements like cadence, foot placement, and foot clearance are the gait characteristics (Winter, 1980) that will be used in this study to evaluate which method of descending stairs will present the least hazard for falls. Simoneau et al. (1991) investigated the falling mechanism during stair descent. They stated that proper foot clearance and accurate foot placement were crucial in determining the perceptual location of the step, as well as ensure proper balance while descending. This study stated that "the misjudgement of the step location may lead to falls due to the foot meeting the step improperly or the foot slipping off the edge of the step because on an excessively anterior foot placement" (Simoneau et al., 1991) or the placement of the tip of the foot in front of the edge of the step may also be an important source of sensory information. By increasing the foot clearance one would provide a better positioning of the foot (Townsend et al., 1991; Simoneau et al., 1991) on the step and ensure balance and stability (Andriacchi et al., 1980; Wyatt et al., 1999) reducing then risk of falls.

Sailors and fire fighters address stairs differently than the usual fashion way. They descend stairs backwards due to steeper stair's structure. They adapted their technique to the structural environment and to their needs. It could be the same for the part of the population with certain difficulties accessing stairs. Looking at descending stairs differently could provide an alternate perspective allowing a certain sense of autonomy. One of these alternatives would be to engage stairs using backward stepping. In doing so, one could increase stability (Andriacchi et al., 1980; Wyatt et al., 1999) due to slower cadence, better foot positioning by increasing foot clearance and reducing slipping and/or sliding. Better depth perception (the subject's looking at the steps upwards or just ahead) could increase (Startzell et al., 2000) providing a sense of security causing less hesitation and fear. We should see smaller peak moments and forces at the lower extremities reducing the strength required to perform the task. The main problem will be the unfamiliar approach that might require training to increase confidence and familiarity with the new way of descending.

Summary

It is apparent that biomechanical studies on the use of stairs have taken on many different roles. Some studies have used kinematics, EMG, or kinetic data to look at the basic gait characteristics of stair walking. Some others have combined two or more of these data collection methods to get more complex information on what joints of the lower extremities are experiencing while doing these tasks (information like moment and power), and finally, some studies have used similar variable methodologies by combining kinematics and kinetic data, to compare the gait of certain groups or the biomechanical effectiveness of different physical therapy aids (AFO's, knee replacements, etc).

In the literature, gaps exist for stair climbing studies. In looking at the task of manoeuvring on stairs, the literature has shown that, specifically, descending the stairs can be a dangerous and physically challenging task in everyday life. Conversely, studying the potential for slipping inducing a possible fall has not been studied very thoroughly. It is the purpose of this study to begin with the basic dependent variables in descending stairs such as moment, power, foot position and time and test them using subjects from a normal young population to create baseline data on descending the stairs. This study will then go further and make a comparison of these dependent variables under two experimental conditions, namely descending stairs forwards compared to descending stairs backwards and compare them to Winter's normal level walking. This is comparison has not yet been done in the literature. This information could prove to be important in the potential to reduce the risk of falling.

Chapter 3

METHODOLOGY

Population and Sample

One purpose of this study was to create baseline information for future studies on stair descent. Because little information exists in this area, before an analysis of special populations can be done, data needed to be collected that represent the able bodies population. Therefore, the subjects chosen to represent the population were between the ages of 20 and 35, with no previous history of lower extremity joint problems. This study used a sample size of 10 subjects (6 men and 4 women). The heights of these individuals were as follows: 1.65 m ± 3 cm, 1.73 m ± 3 cm, and 1.80 m ± 3 cm. The reason for controlling the heights of the subjects was due to evidence that height affects cadence (Murray, 1970; Livingston, 1991) and the joint angles of the lower limbs on a given set of stairs (Hughes, 2000; Livingston, 1991; McCrory and Gilchrist, 2000; Sparrow, 1998). During all trials, participants were required to wear minimal clothing: dark dance tights and short, black T-shirt and shoes. All subjects participating in the project provided informed written consent according to the protocol approved by the Human Research Ethics Committee of the University of Ottawa (see Appendix 1, 2 and 3).

Apparatus

Both kinematic and kinetic data were collected for each subject, and for each method of descending the stairs. One high-speed Panasonic camera (60 fps) was used to record the 2 single foot contacts onto platforms 1 and 3 (Fig.3). The camera was perpendicular and set at a distance of 4.27 m from the subject. The video acquisition area was calibrated with a 2 x 1.1 m calibration frame (16 control points).

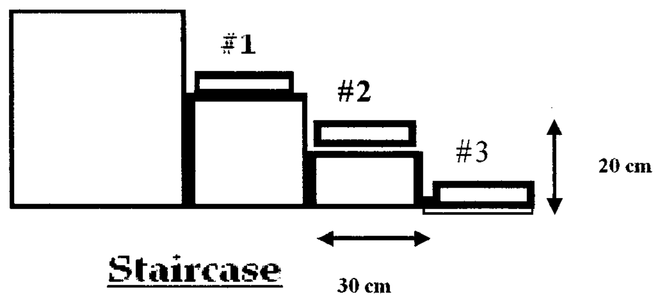


Figure 3: Schematic diagram of the custom built wooden staircase with the Force Plates one and two used to perform forward and backward stairs descent. All steps were 20 cm rise and 30 cm run.

To collect the kinematic data, 7 markers were placed on one side of the subject to distinguish the body segments of the lower limb. Markers were placed at: iliac crest to toe. Namely: (1) iliac crest, (2) greater trochanter of femur, (3) lateral condyle of tibia, (4) lateral malleolus of fibula, (5) lateral calcaneous, (6) lateral metatarsal-phalangeal joint and, (7) extremity of big toe.

The stair reaction force data were collected through the use of multi-component force plates measuring ground reaction forces (200 Hz) and moments. Two force platforms (Kistler 9286A {#1} and 9281C {#3}) were fixed on the ground and second last step of the staircase.

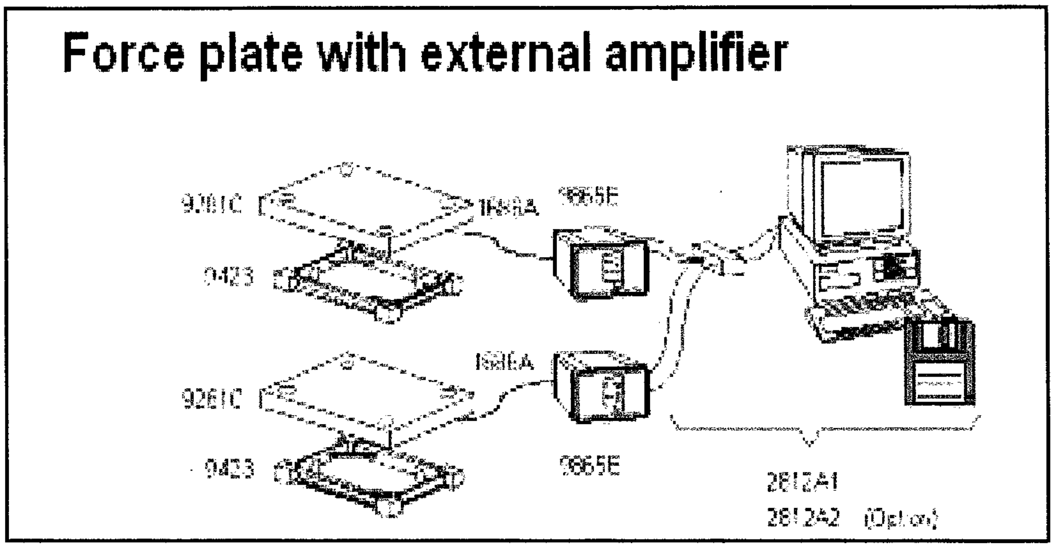


Figure 4: Schematic diagram of the multi-component Force Plate "Kistler" combined to an amplifier and to a computer. (http://www.health.uottawa.ca/biomech/lab/equip.htm)

The staircase was an adjustable structure where the bottom section was made of aluminium, the second and third out of wood (Fig. 4). The starting surface at the top was larger to provide better subject's preparation. The stairs' rise was 20 cm with a run (or tread length) of 30 cm (CSA: Provincial; OBC: Ontario Building Code). The run size was selected as it provides a safe tread length based on the average foot size of North Americans (Livingston et al., 1991; Asher, 1977; Irvine et al., 1990; Bradford et al., 1988).

A laboratory computer equipped with Kistler Bioware software and a 16-channel A/D converter recorded the data. Video data were processed by the Ariel Performance Analysis System.

Protocol

Each subject answered a short questionnaire (Appendix 4) and then a data file was created with a code representing the subject. The seven markers were placed at each joint and segment lengths measured with an anthropometer. The subjects were required to descend the stairs forwards at their own pace, then backward at own pace and finally forwards again but at the same pace as for backwards. A metronome was used to regulate the pace of the second set of forwards' descent. All subjects were required to initiate stair descent with the right foot and taking two more steps at the end of the staircase to avoid changes in the pace and gait pattern. Each subject completed five trials for each method with warm-up before each sequence.

Analysis

For the purpose of this experimentation, only one step cycle was analyzed (step #1). The Biomech Motion Analysis Software (http://www.health.uottawa.ca/biomech/csb/software/biomech.htm) calculated the inverse dynamics for each joint based on the kinematics and kinetic data collected. A comparison between forwards, backwards and slow forwards stair descent to Winter's level walking of the moment powers at the ankle, knee, and hip joints was made.

Labelling

Unlike Winter's moment powers labelling phases (Fig. 5) (next page) at ankle (A1, A2), knee (K1, K2, K3, K4) and hip (H1, H2, H3) (Winter, 1991) we gave our own labels to show the multiple moment power phases of the stair descent. As an example the Figure 6 shows the more important phases labelled as SA0, SA1 and SA2 for the ankle and SK1, SK2, SK3 and SK4 for the knee.

Statistics

Each subject's trial (5) for each conditions were time normalized and averaged. Then, each subject's ensemble averaged data were normalized to body mass and ensemble averaged across to obtain a grand ensemble (GE) for forward, backward and slow forward stair descent.

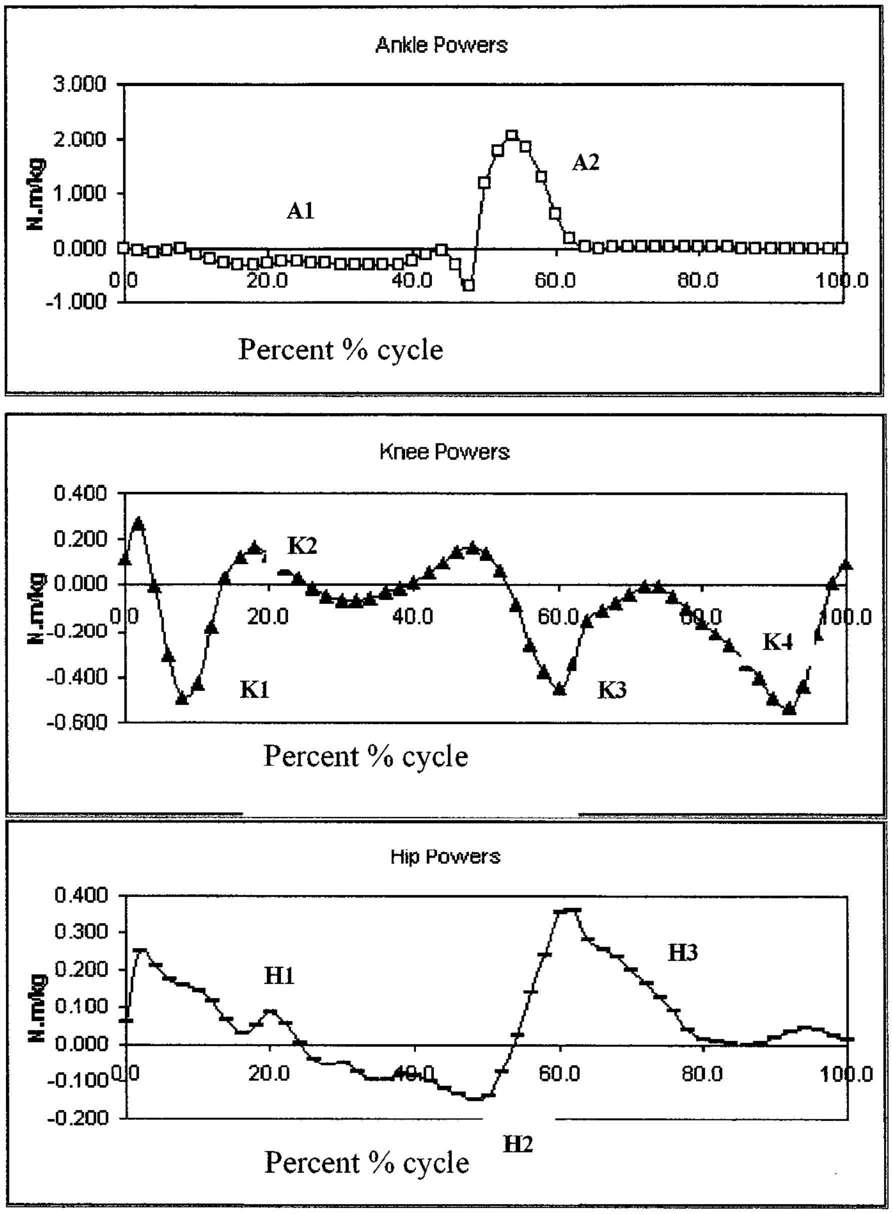


Figure 5: Winter's natural level walking most important phases labeled ankle (A1 and A2), kne (K1, K2, K3 and K4) and hip (H1, H2 and H3)

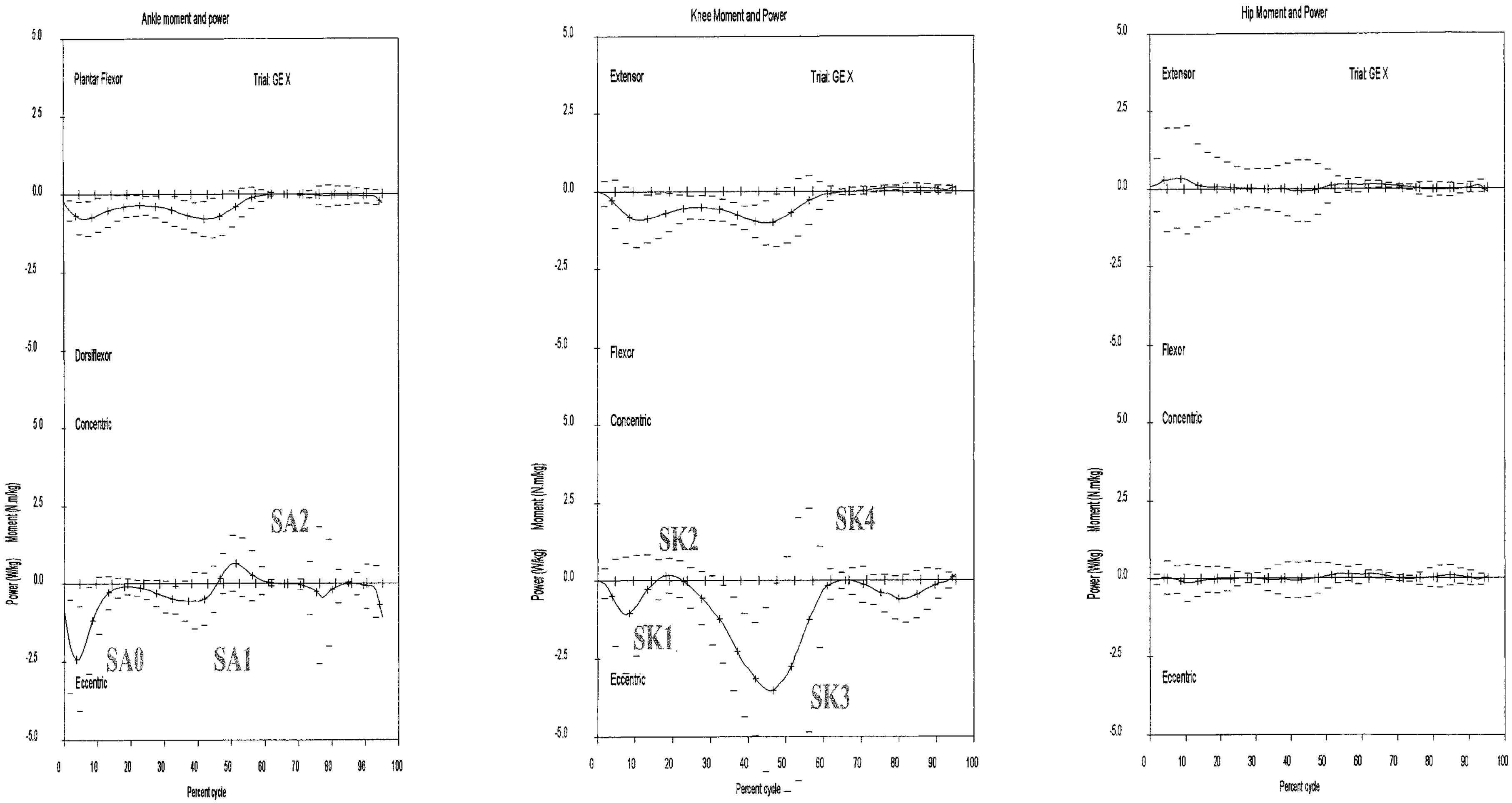


Figure 6: Stair descent sample of the more important phases labeled ankle (SA0, SA1 and SA2), knee (SK1, SK2, SK3 and SK4). In stair descent the hip wasn't labeled.

Chapter 4

RESULTS

In this section a temporal analysis of forward and backward stair descent will be made. Next, we will compare the differences in the support moments and moment powers of Winter's level walking data (1991) with data from stair descent. Since Winter's data are presented as body mass normalized ensemble averages the same process was applied to the results of this study. Thus, each subject's trials (5) for each condition were time normalized and averaged. Then, each subject's ensemble average data were normalized to body mass and ensemble averaged to obtain a grand ensemble (GE) for each condition. Next, we will compare backward and slow forward descent. Finally, an analysis of the horizontal foot position to the edge of the step and a comparison of the different moment powers at the lower extremities will be made.

It was important to make a clear distinction between level walking and stair descent moment powers. In Figure 6 the more important phases were labelled as SA0, SA1 and SA2 for the ankle and SK1, SK2, SK3 and SK4 for the knee. Because of minimal activity recorded we didn't label the hip.

Level walking and stair descent

For comparison, one subject (JC) was chosen to provide contrasting results with the data from Winter (1991). The Biomech Motion Analysis Software computed the 5 trials support moments of the subject by adding the 3 moments:

$M_{support} = - M_{ankle} + M_{knee} - M_{hip}$ (Winter, 1980) and normalizing to body mass. Moment powers were computed from the product of the joint angular velocities and the moments of force: $\boldsymbol{P_j} = \boldsymbol{M_j} \cdot \boldsymbol{\omega_j}$ (Winter, 1980), and normalized to body mass.

The stride cycle was calculated foot-strike to foot strike; initial foot strike (IFS) to *toe-off* (TO), indicated by a vertical line in the next figures. When compared to Winter' level walking (Fig. 7), forward stair descent (Fig. 8) and backward stair descent (Fig. 9), show an average stance phase of 63 to 70% of cycle versus a 60% stance phase for level walking. In forward and backward descent we observed larger support moments with similar double peaks as walking. We also observed a larger variability at the second peak of the support moments (arrow on support moment of Figure 8) in the forward stair descent compared to backward stair descent (Fig. 9).

Forward and Backward Descent

A temporal analysis using a t-test was performed on the grand ensemble average of forward and backward stair descent. Results showed an augmentation of time (from the first step *toe-off* to the last step *toe-off*) when using backward descent (Table 1).

Table 1: Average (5 trials) descent time (s) of natural paced, forward and natural paced, backward stair descent using 9 subjects. The time of descent started from the first step toe-off to the second step toe-off (one cycle).

Subject	1	2	3	4	5	6	7	8	9
N-Forward	1.1800	1.2330	1.0066	1.1200	1.1666	1.0802	1.3934	1.0468	0.9802
N-Backward	1.4500	1.1920	1.4665	1.5168	1.4066	1.3934	1.1333	1.5398	1.0468

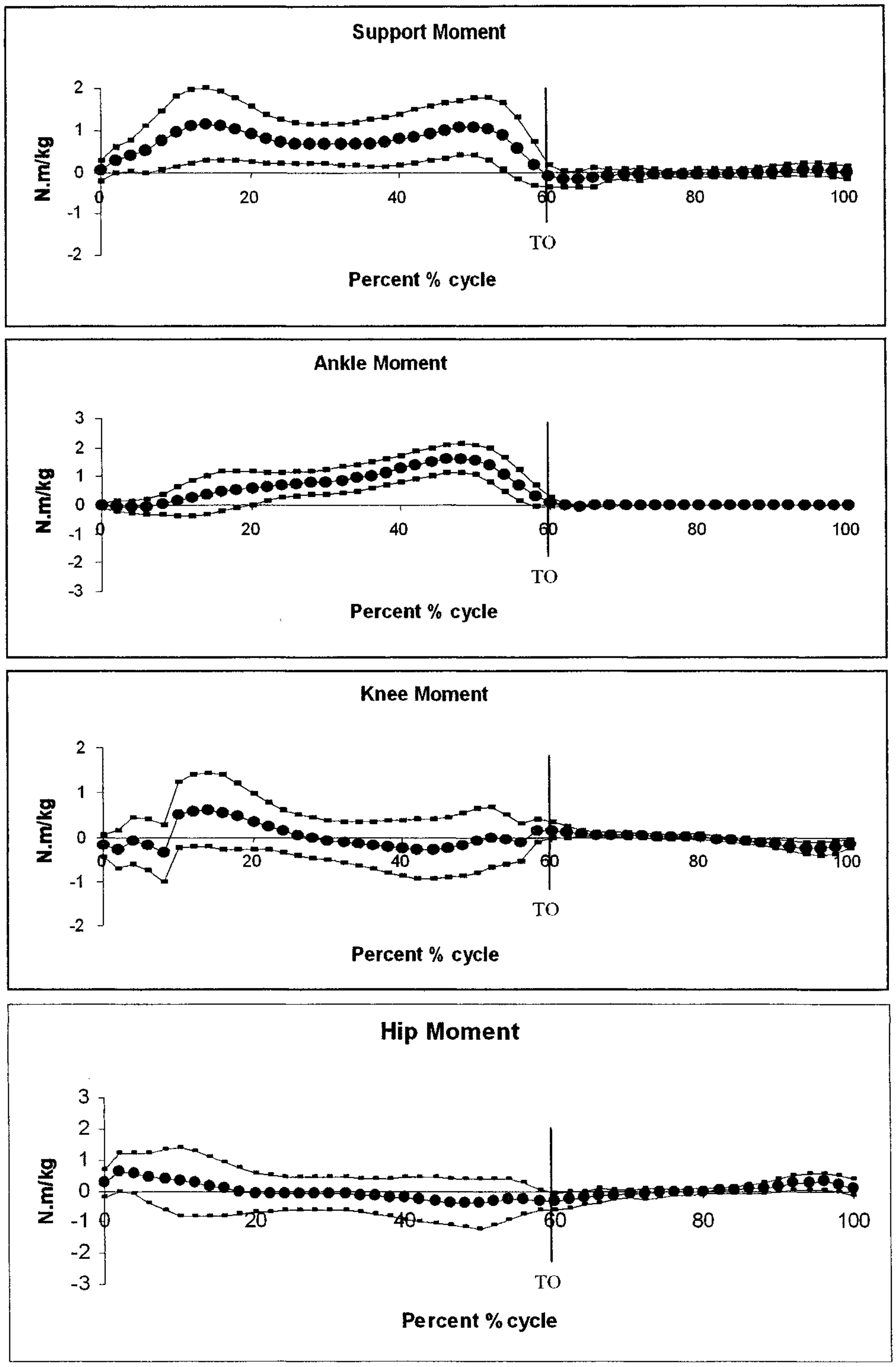


Figure 7: Winter's natural level walking showing the support moment and moments at Ankle, Knee and Hip using a Confidence Interval of 95%. The IFS (initial foot-strike) is located at 0% and the vertical line represents the TO (toe-off).

*Note: Reference Winter, (1991) Figure 4.23 on page 40

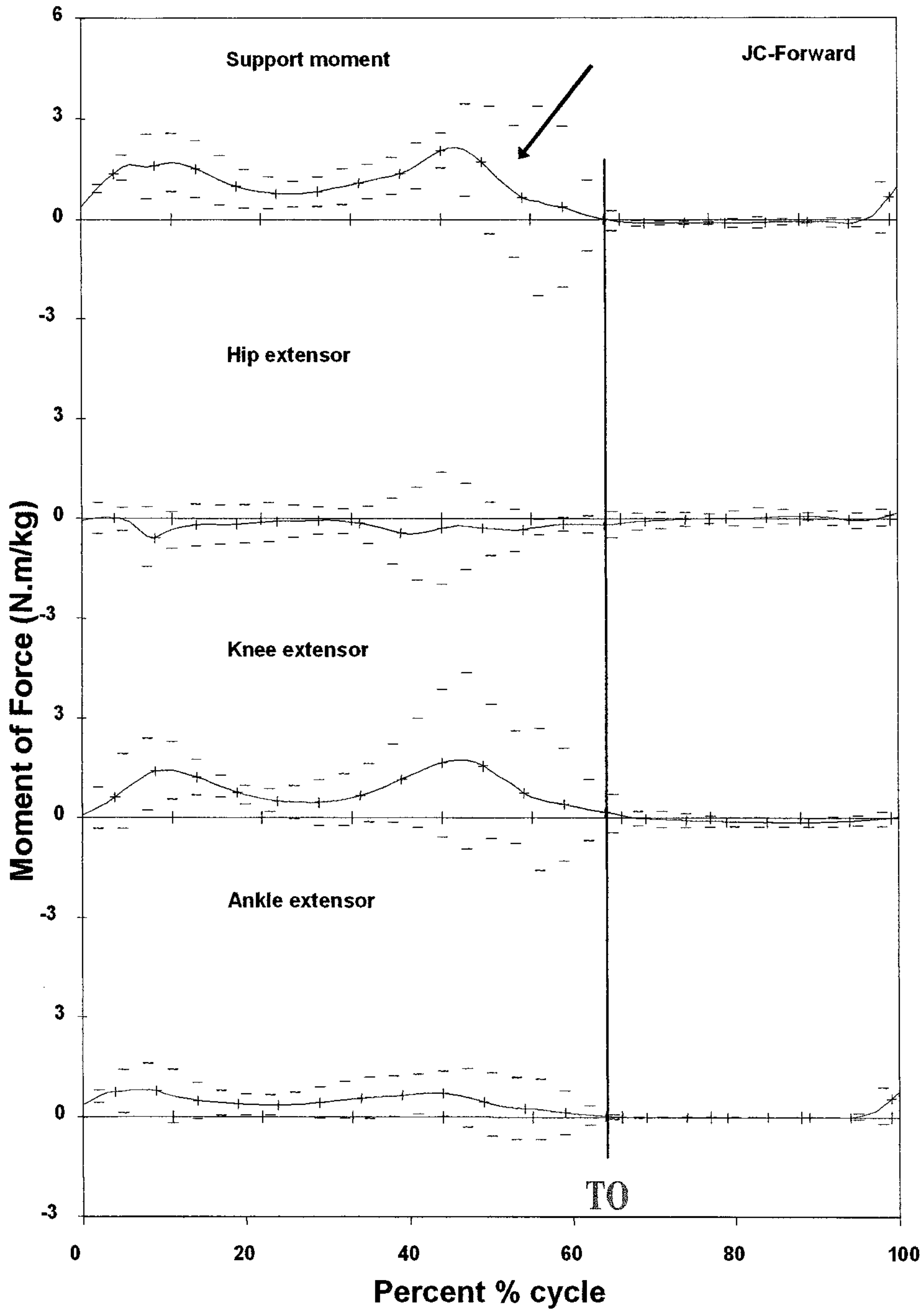


Figure 8: Ensemble averages and confidence intervals of extensor and support moments for subject JC during forward stair descent. The IFS is located at 0% and the vertical line represents the TO after 60%.

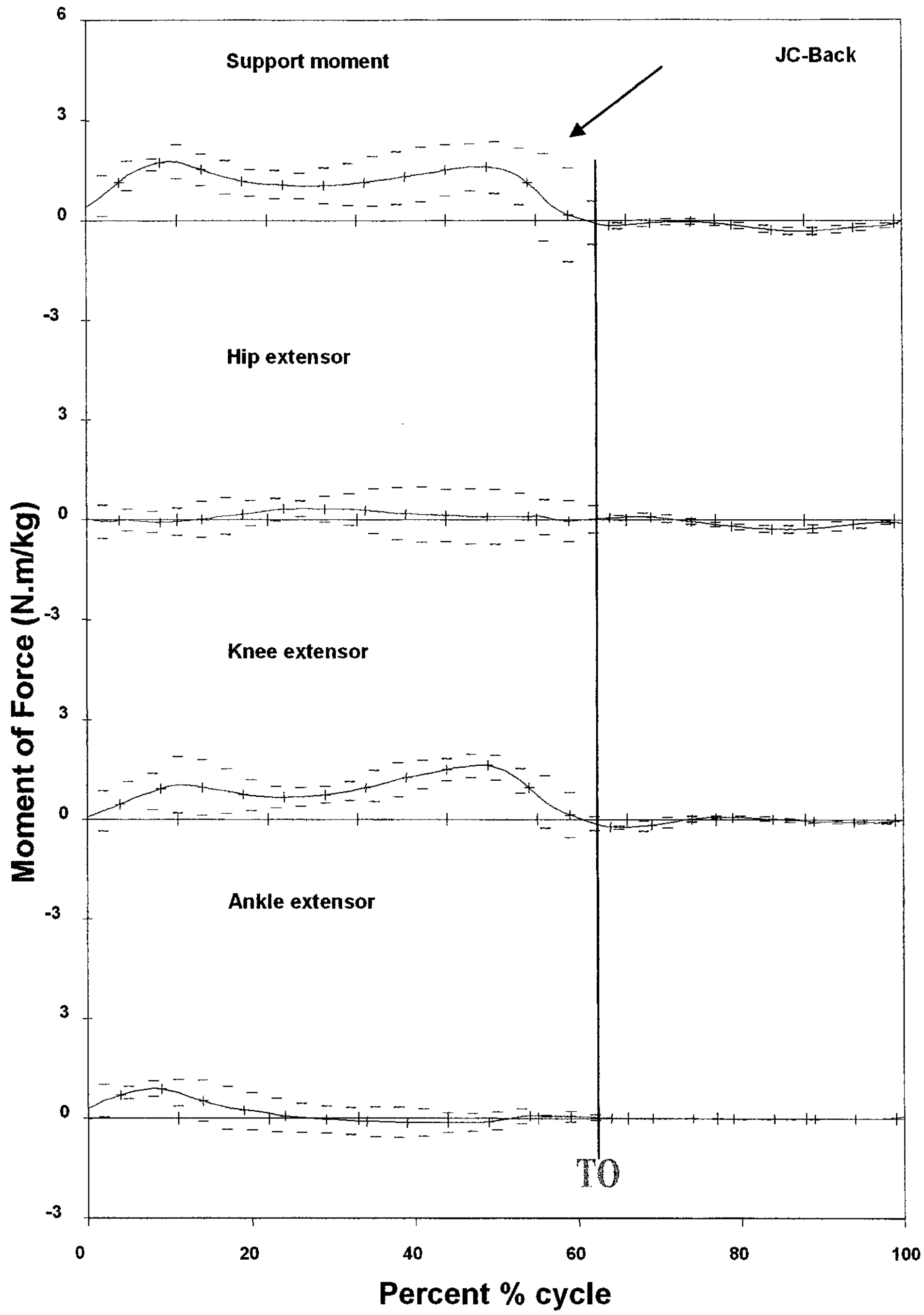


Figure 9: Ensemble averages and confidence intervals of extensor and support moments for subject JC during backward stair descent. The IFS is located at 0% and the vertical line represents the TO after 60%.

There was a significant difference in average cycle duration (from *toe-off* to *toe-off*) for forward descent of 1.134 s compared to 1.349 s for backward descent ($P<0.03$). Because of this time difference between forward and backward descent only the slow forward's moments and powers will be compared to the backwards descents.

Slow Forward and Backward Descent

The subject's backward descent (JC) (Fig. 10) and the GE's backward descent (Fig. 11) show smaller support moment variability (between 40 and 65% of the cycle) compared to the subject's slow forward descent (Fig. 12) and the GE's slow forward descent (Fig.13). We still observed similar double support moment peaks as in walking (Fig. 7) but larger. In backward descent the first peaks were larger and the second peaks smaller whereas in slow forward descent both peaks were with similar magnitude. The second peak showed smaller variability compared to slow forward. We observed one major ankle extensor burst at 10% of cycle compared to three bursts in slow forwards descent. The knee extensor showed certain similarity but moment of force for backwards descent were larger at second and fourth burst (SK2 and SK4) (16% and 65% of cycle) and smaller at the second burst (44% of cycle). At hip level, we observed similar low moments of force with large variability than slow forward descent. The horizontal position centre of pressure of the ground reaction forces were computed (Table 2) and statistically compared to show a significant difference ($P<0.001$) between backward and slow forwards descent foot positioning to the edge of the step on the force plate.

Table 2: Average (5 trials) horizontal distance from stair edge to centre of pressure of the ground reaction force integrated over time for backward and slow-forward stair descent (same pace as backward)

Subject	1	2	3	4	5	6	7	8	9
Forward	10.4930	8.4744	8.6270	9.9360	7.9481	8.6370	9.1374	9.1320	8.0772
Backward	5.6750	7.0870	5.0481	8.7055	3.4969	3.9928	5.3739	3.9470	7.5022

Compared to Winter's level walking moment powers (Fig. 21), JC and the GE's slow forward and backward stair descents at the ankle level show no initial dorsiflexor phase (Fig. 14 and 15). At around 5% of the cycle, we observed a larger peak which we named (SA0), showing a strong plantar flexor eccentric phase in contrast to walking where this increase occurs later. Right after, we observed a much smaller plantar flexor concentric phase in slow forward and backward descent. The knee ((Fig. 16 and 17) had little to no concentric extensor phase (SK2 and SK4) in slow forward descent whereas in walking and backward descent SK2 and SK4 had concentric extensor phase occurring during midstance. The SK1 and SK3 were similar to walking showing an eccentric extensor burst for both types of descent. The main difference in slow forward and backward descent was that the SK3 were larger. Negative flexor power was visible throughout the swing phase as in level walking. The hip moment powers (Fig. 18 and 19) were minimal compared to walking where some activity usually occurred. The slow forward descent (Fig. 18) showed larger variation compared to level walking and backward descent.

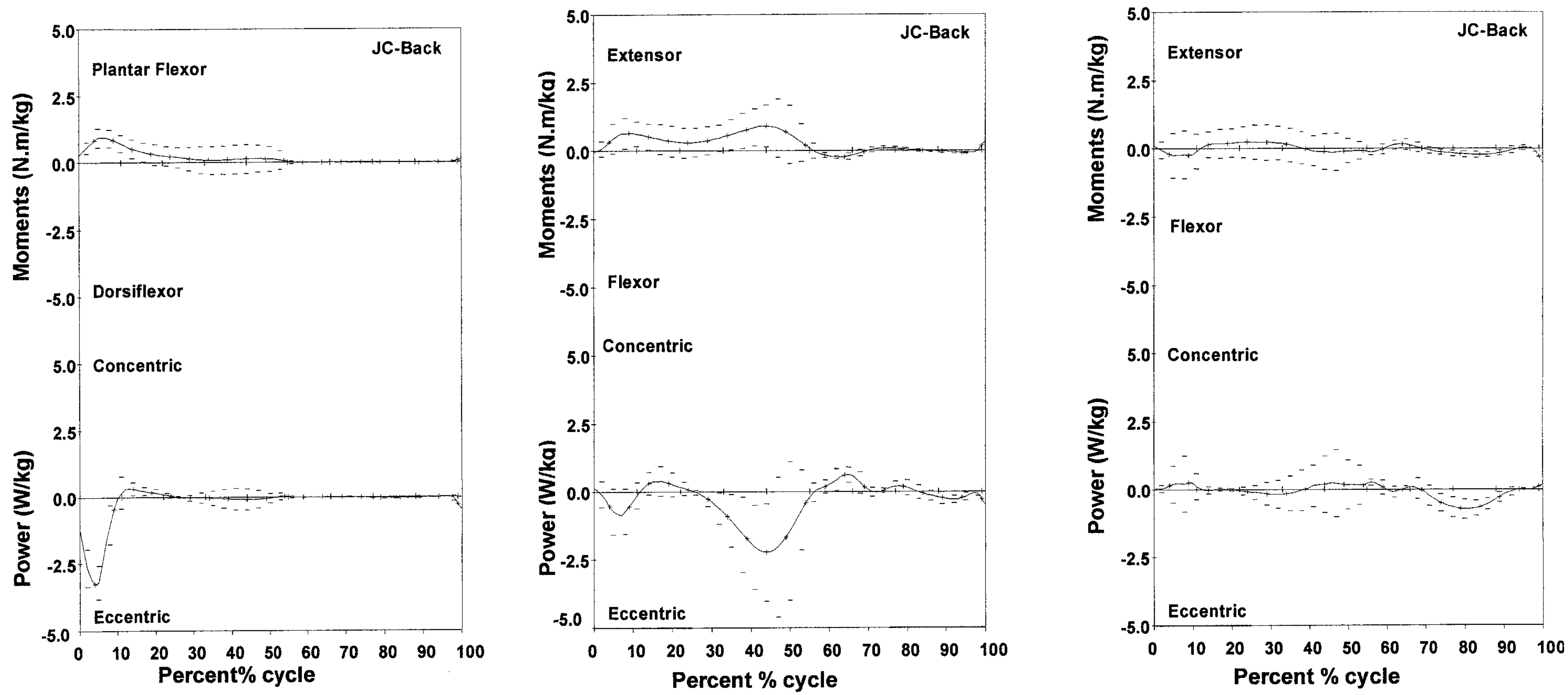


Figure 10: Ensemble averages and confidence intervals of the ankle, knee and hip moment and powers for subject JC during backward stair descent.

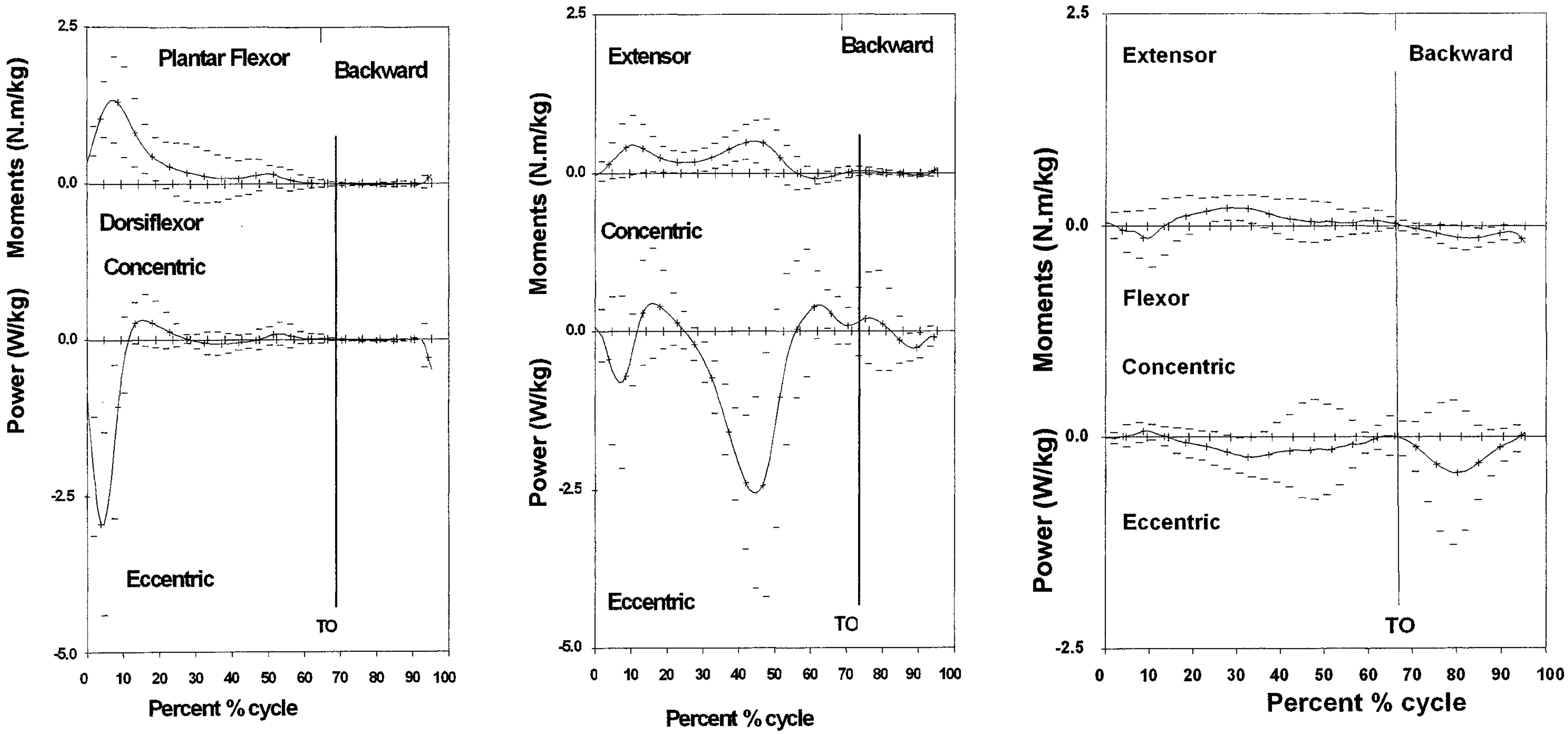


Figure 11: Ensemble averages and confidence intervals of the ankle, knee and hip moment and powers for (GE) grand ensemble during backward stair descent. The IFS (initial foot strike) is located at 0% and the vertical line represents the TO (toe-off).

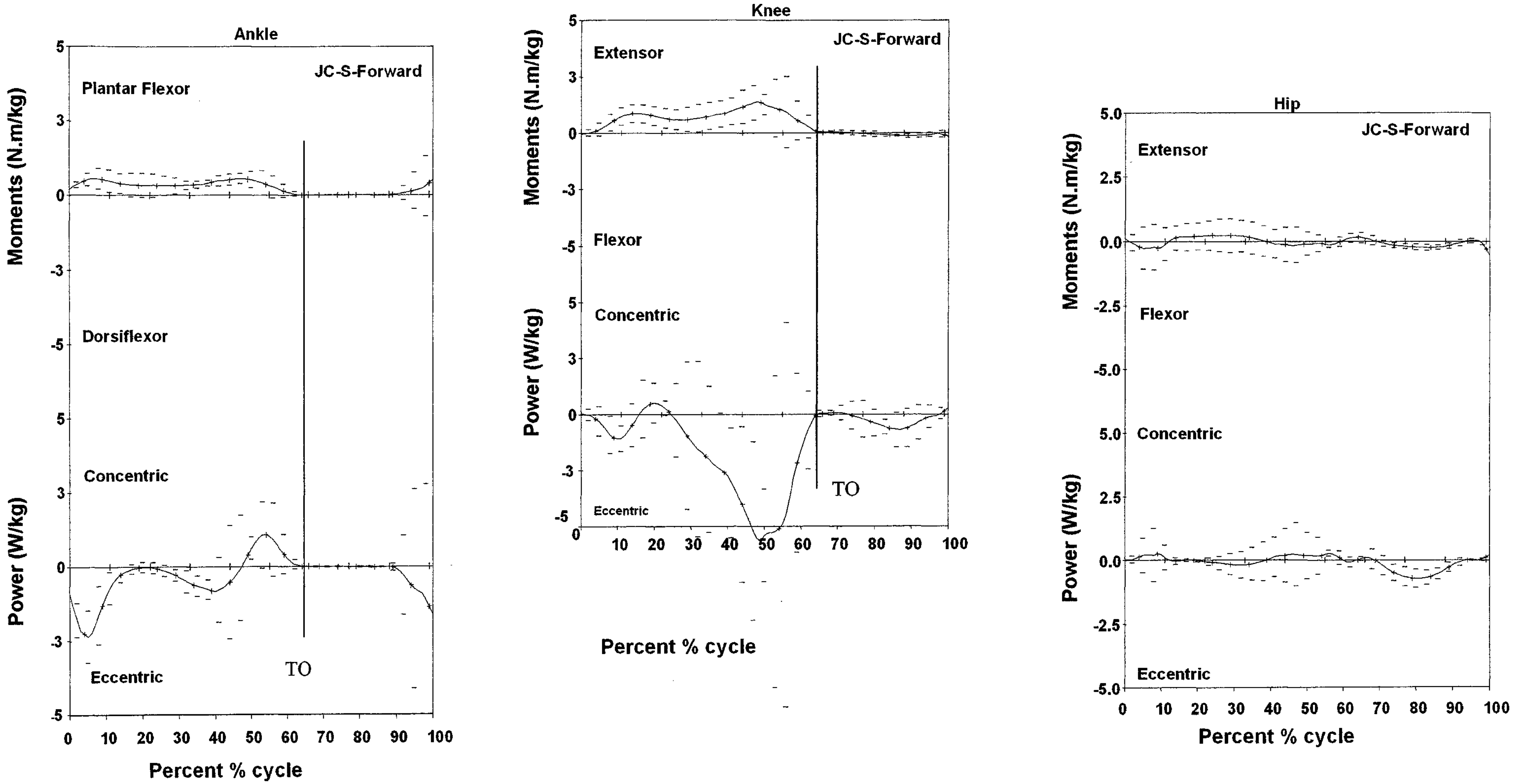


Figure 12: Ensemble averages and confidence intervals of the ankle, knee and hip moment and powers for subject JC during slow forward stair descent. The IFS (initial foot strike) is located at 0% and the vertical line represents the TO (toe-off).

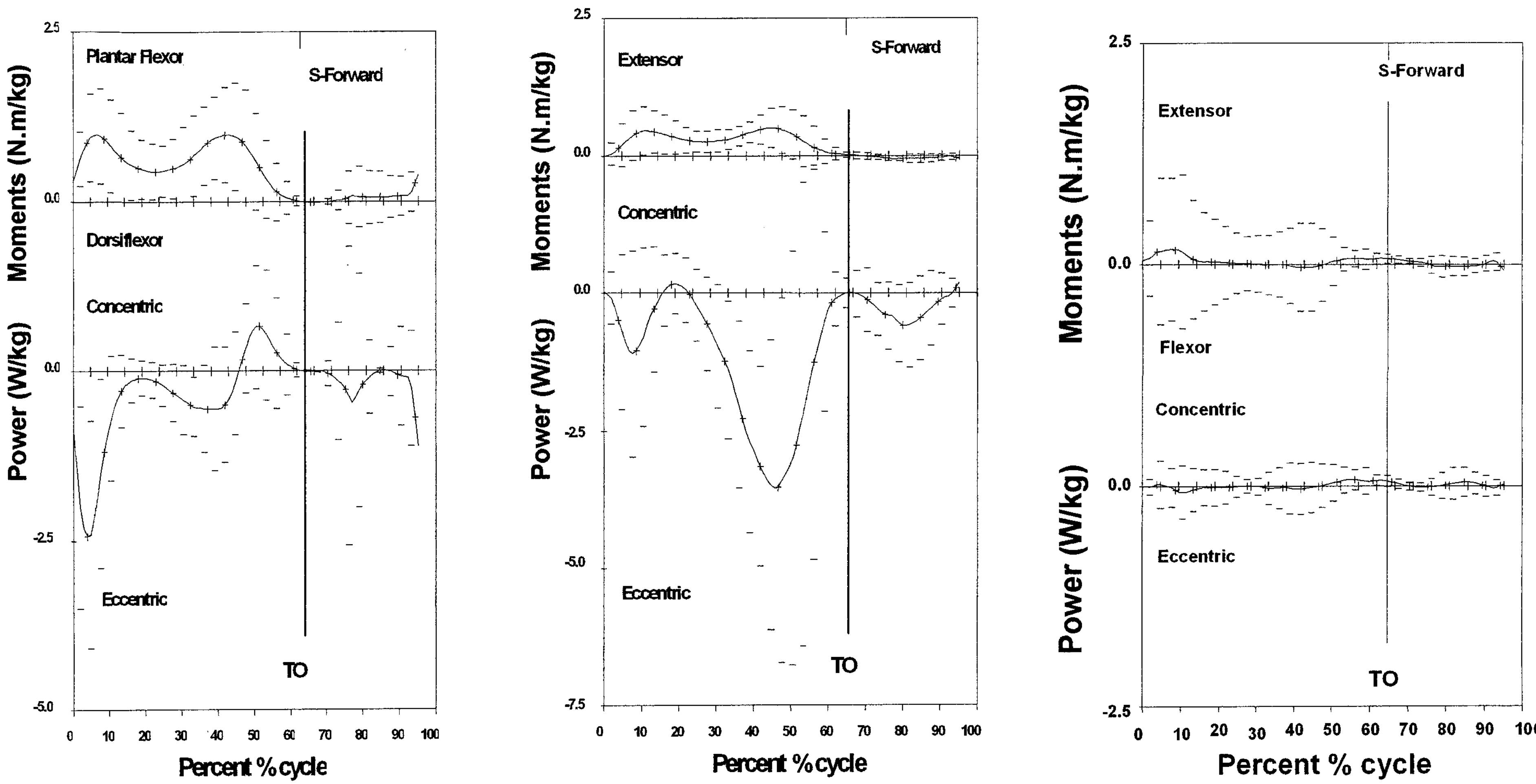
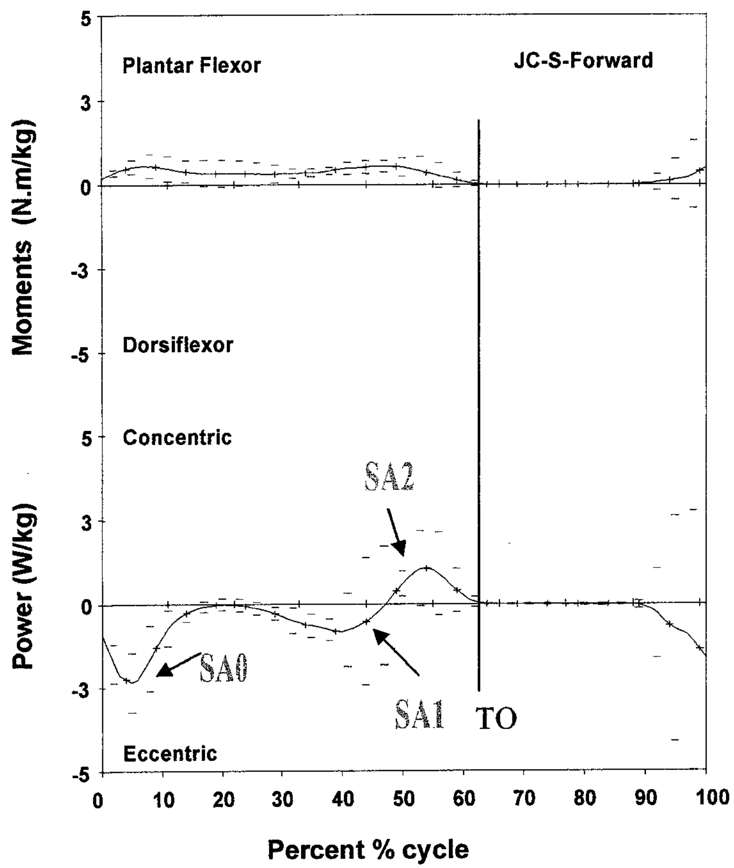


Figure 13: Ensemble averages and confidence intervals of the ankle, knee and hip moment and powers for (GE) grand ensemble during slow forward stair descent. The IFS (initial foot strike) is located at 0% and the vertical line represents the TO (toe-off).



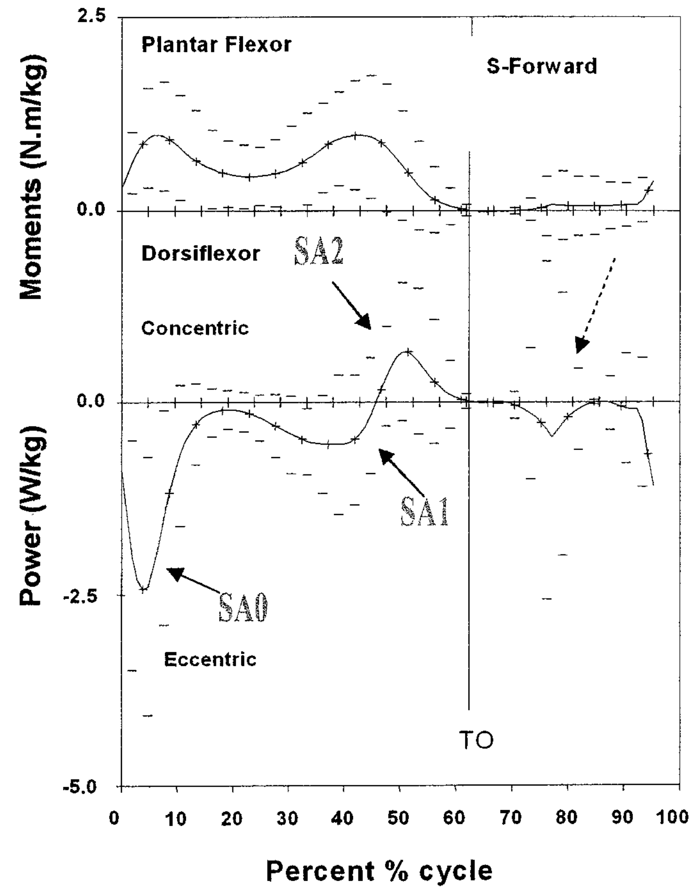
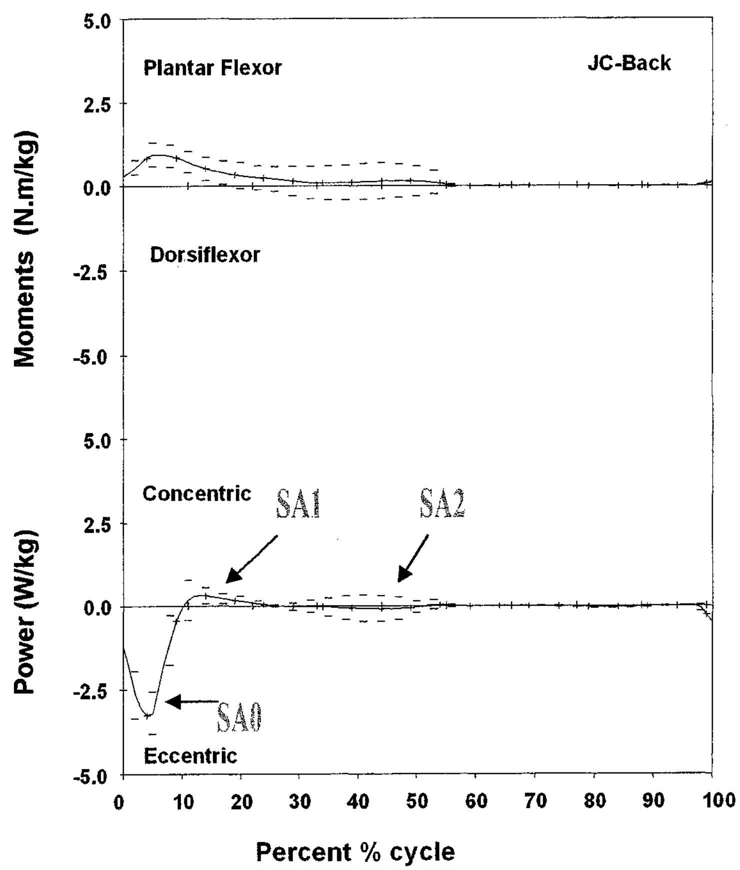


Figure 14: Ensemble averages and confidence intervals of the ankle moment and powers for subject JC and Grand Ensemble GE during forward and slow forward stair descent. The IFS (initial foot strike) is located at 0% and the vertical line represents the TO (toe-off).



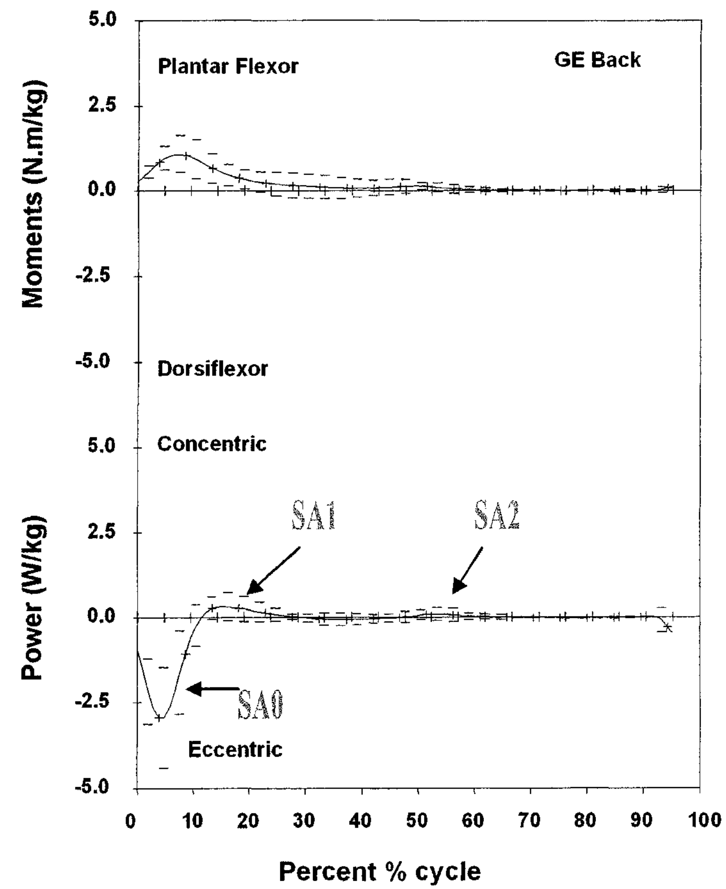


Figure 15: Ensemble averages and confidence intervals of the ankle moment and powers for subject JC and Grand Ensemble GE during backward stair descent.

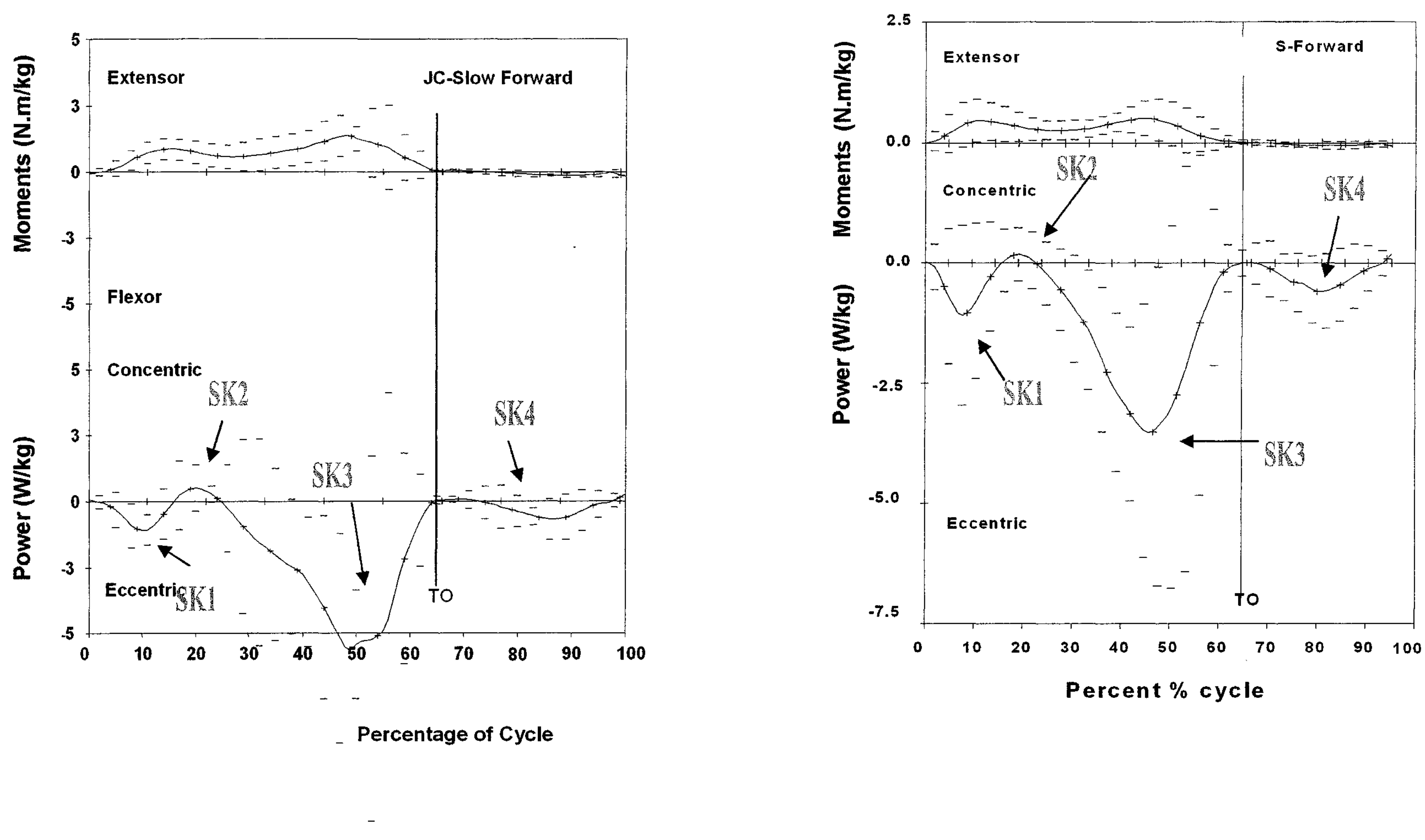


Figure 16: Ensemble averages and confidence intervals of the knee moment and powers for subject JC and Grand Ensemble (GE) during slow forward stair descent. The IFS (initial foot strike) is located at 0% and the vertical line represents the TO (toe-off).

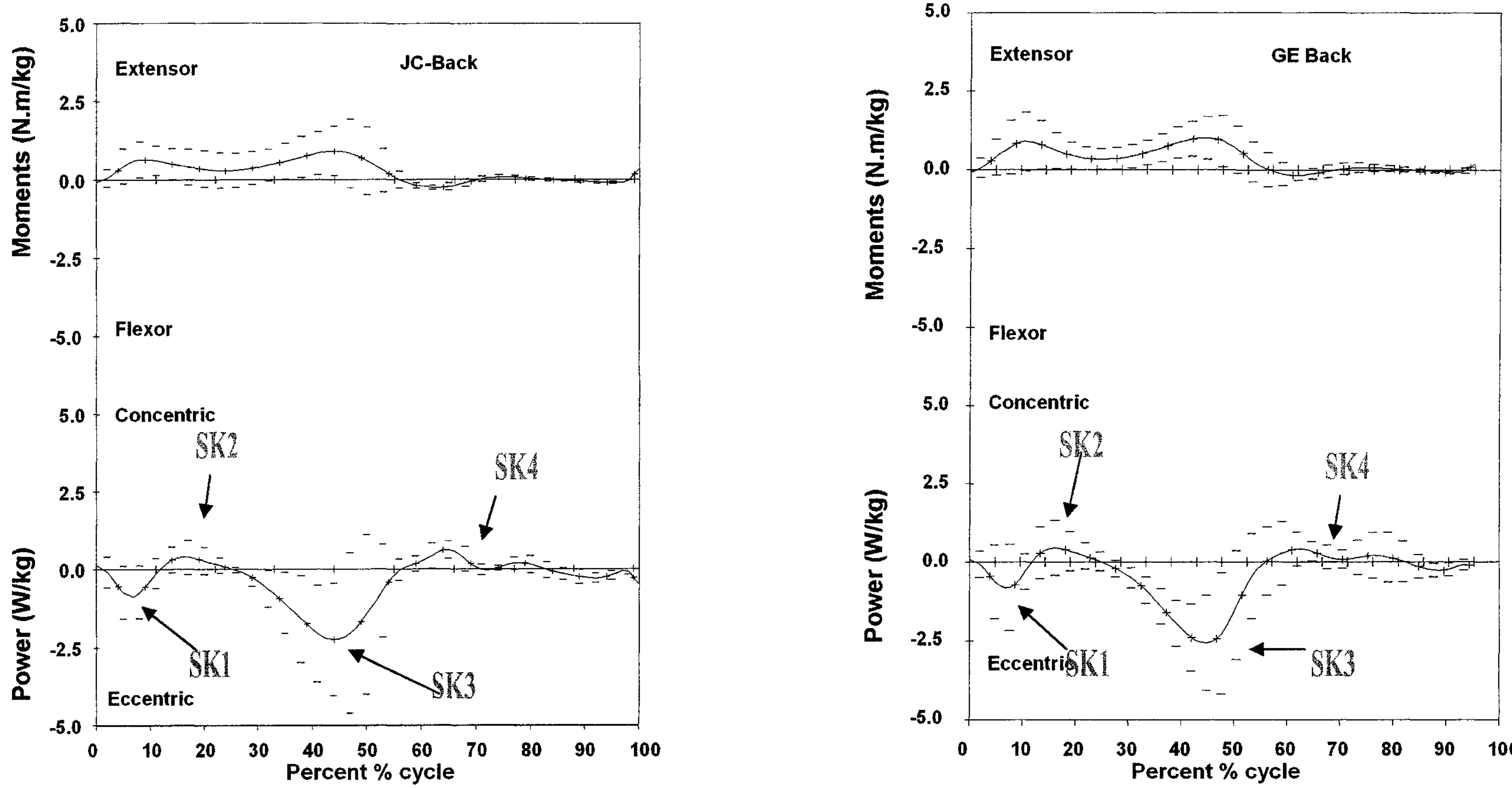
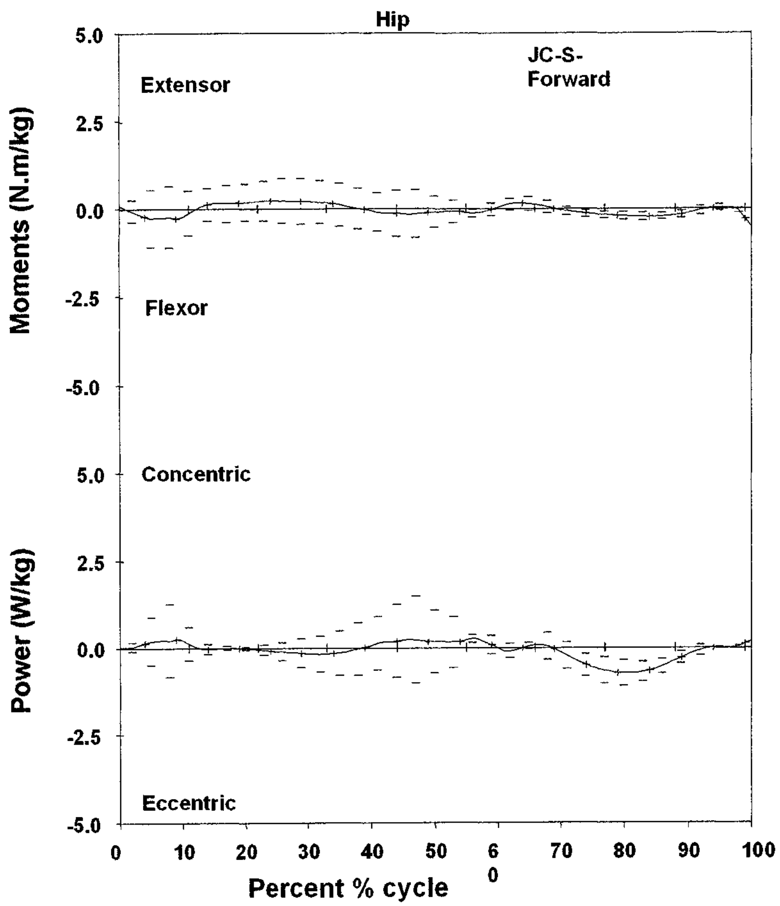


Figure 17: Ensemble averages and confidence intervals of the knee moment and powers for subject JC and Grand Ensemble GE during backward stair descent



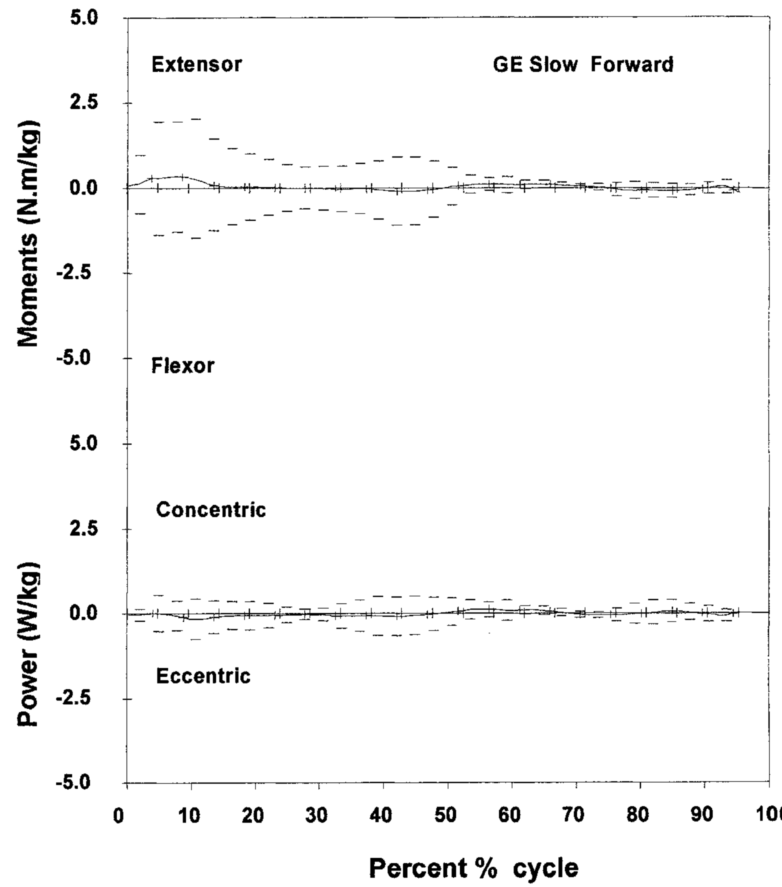
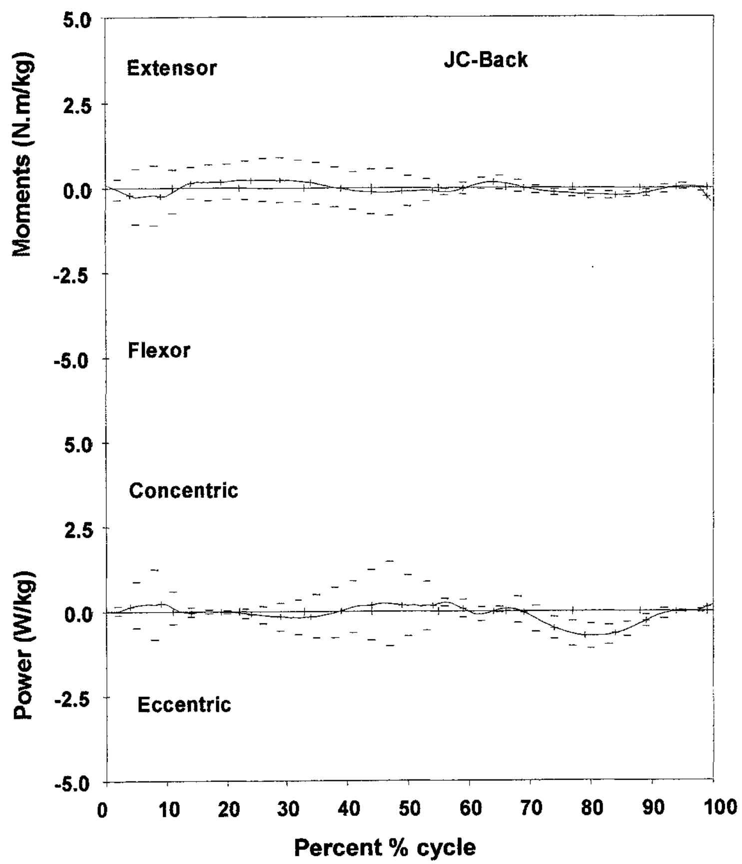


Figure 18: Ensemble averages and confidence intervals of the hip moment and powers for subject JC and Grand Ensemble (GE) during slow forward stair descent.



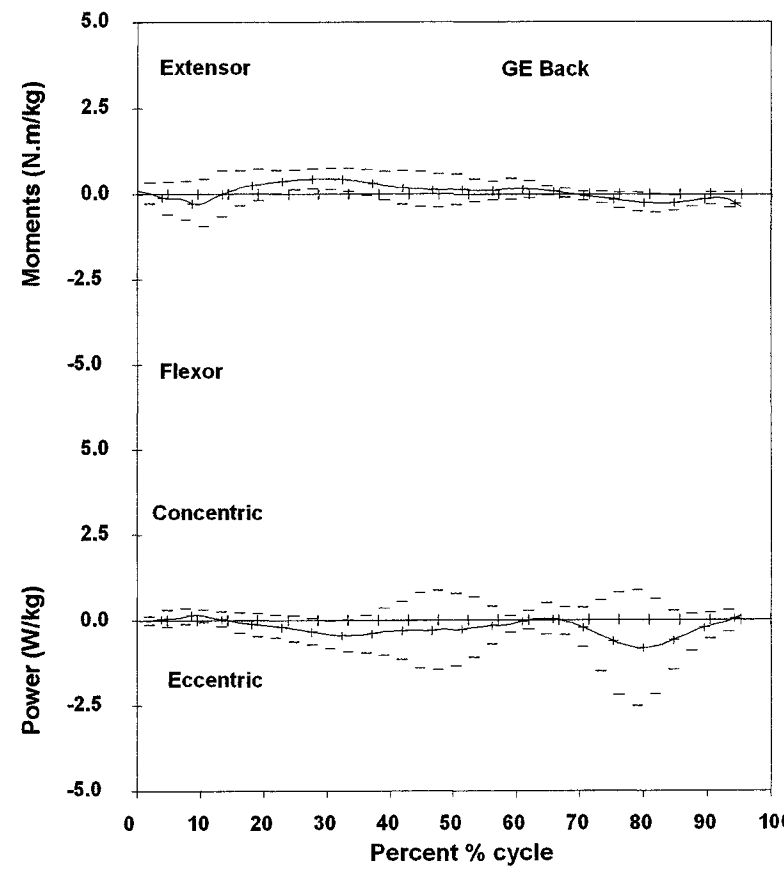


Figure 19: Ensemble averages and confidence intervals of the hip moment and powers for subject JC and Grand Ensemble GE during backward stair descent

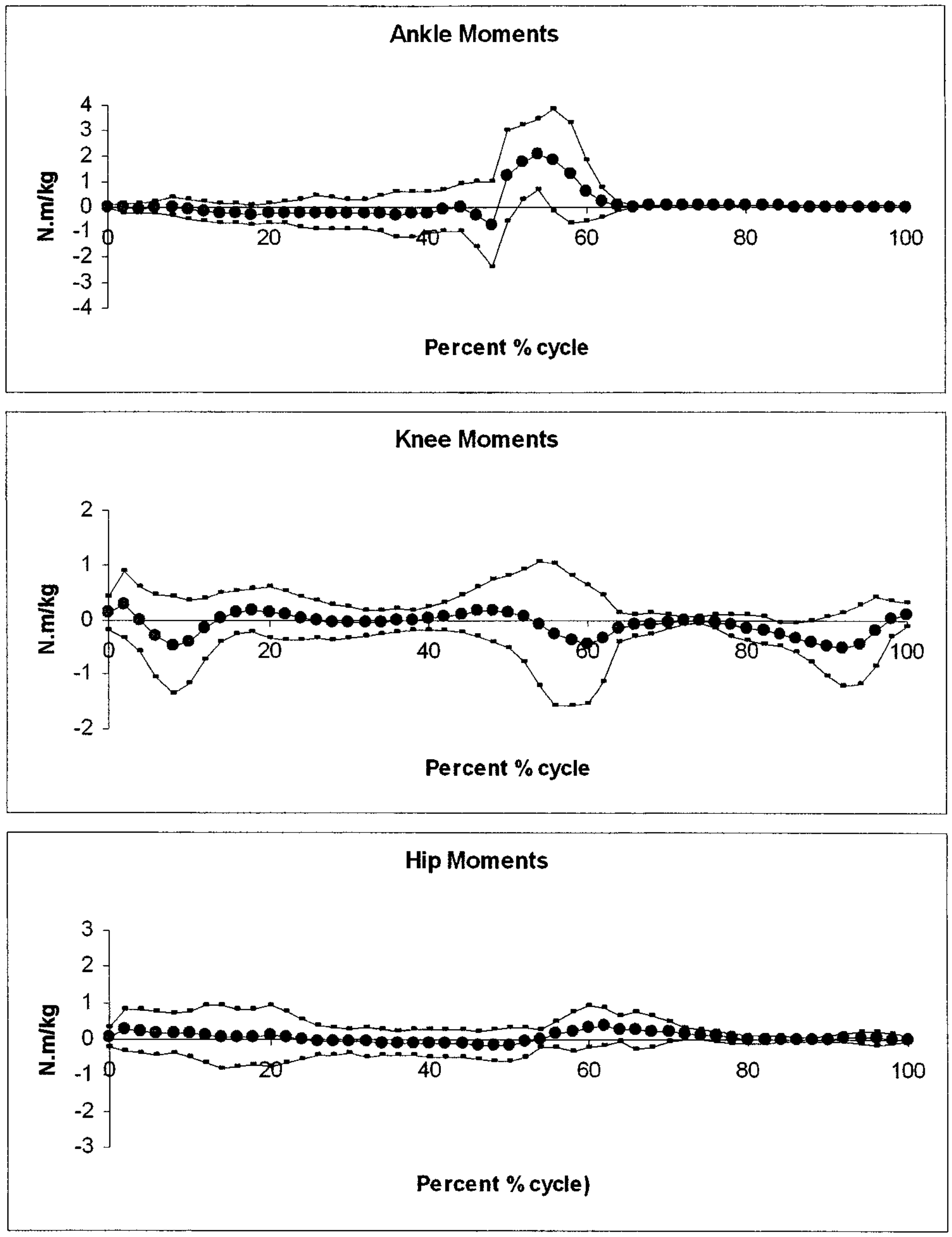


Figure 20: Winter's Level Walking Moments Powers Trials at Ankle, Knee and Hip (Winter, 1991) and using a Confidence Interval of 95%.
*Note: Reference Winter, (1991)

Further analysis of the hip support moments and moment powers won't be made for slow forward and backward descent (Fig.18 and 19) because of the minimal hip moment powers observed.

The subject's and GE's backward stair descent (Fig. 15 and 17) support moments and moment powers were different at the ankle and similar at the knee compared to slow forward descent (Fig 14 and 16). Figures 15 showed an increased ankle plantar flexor moment and a reduction on the second peak whereas in slow forward we observed twin plantar flexor peaks. The knee extensor support moments were similar in both types of descent with a smaller first peak than the second one. The moment powers of the backward descent (Fig.15) showed a larger peak plantar flexor eccentric burst (SA0) at 5% of the cycle (toe-off to toe-off) followed by a small concentric plantar flexor phase. We also observed a smaller peak plantar flexor push-off power (SA2) with less variability when compared to slow forward (Fig. 14). At the knee level (Fig. 16 and 17), the backward descent moment powers showed a slightly bigger concentric extensor phase at SK2. Then, at SK3, a significantly reduced knee extensor eccentric burst (P=0.005) occurred. At SK4 in Figure 17, there was a double extensor concentric phase in backward descent followed by a smaller flexor eccentric phase compare to one small concentric extensor phase followed by an eccentric extensor phase in forward descent (Fig. 16).

DISCUSSION

The aim of this study was to determine if using a backward stair descent was different than a forward descent and Winter's level walking. Secondly we were trying to find out if the foot position was more posterior to the edge of the step.

We started demonstrating the differences between a normal level walking gait from Winter's (1991) subject's trials and forward and backward stair descent using one subject's trials (JC) and a grand ensemble (GE) subjects' average. Winter used a confidence interval of 66.4 and we used a 95% confidence interval. To be able to compare equally our results to his we had to apply the same confidence interval to Winter's data. The 95% confidence intervals were calculated by multiplying ±1.96 times the standard deviations.

The results obtained show the activity of stair descent to be different than Winter's level walking. Stair descent produced similar double peak support moments in both types of descent but with larger variability at the second peak in forward descent (Fig. 20). This variability could be explained by the increased extensor moment required to control the full body weight into a controlled descent.

The support moments increase exceeded Winter's level walking 60% stance phase by 5% to 10% like the results obtained by Townsend et al., (1978). This increase demonstrated an augmentation of time spent in two legs support thus reducing the swing phase. Walking usually has a heel to toe motion whereas stairs was a toe, heel to toe. This activity combined with vertical descent increased the moments thus increasing the loading imposed upon the leg. The entire body centre of mass is put in a forward position to be controlled by the moments of force. So, the time spent on stance phase becomes more important to dissipate the loading. The swing phase becomes less demanding since gravity assists the leg swing.

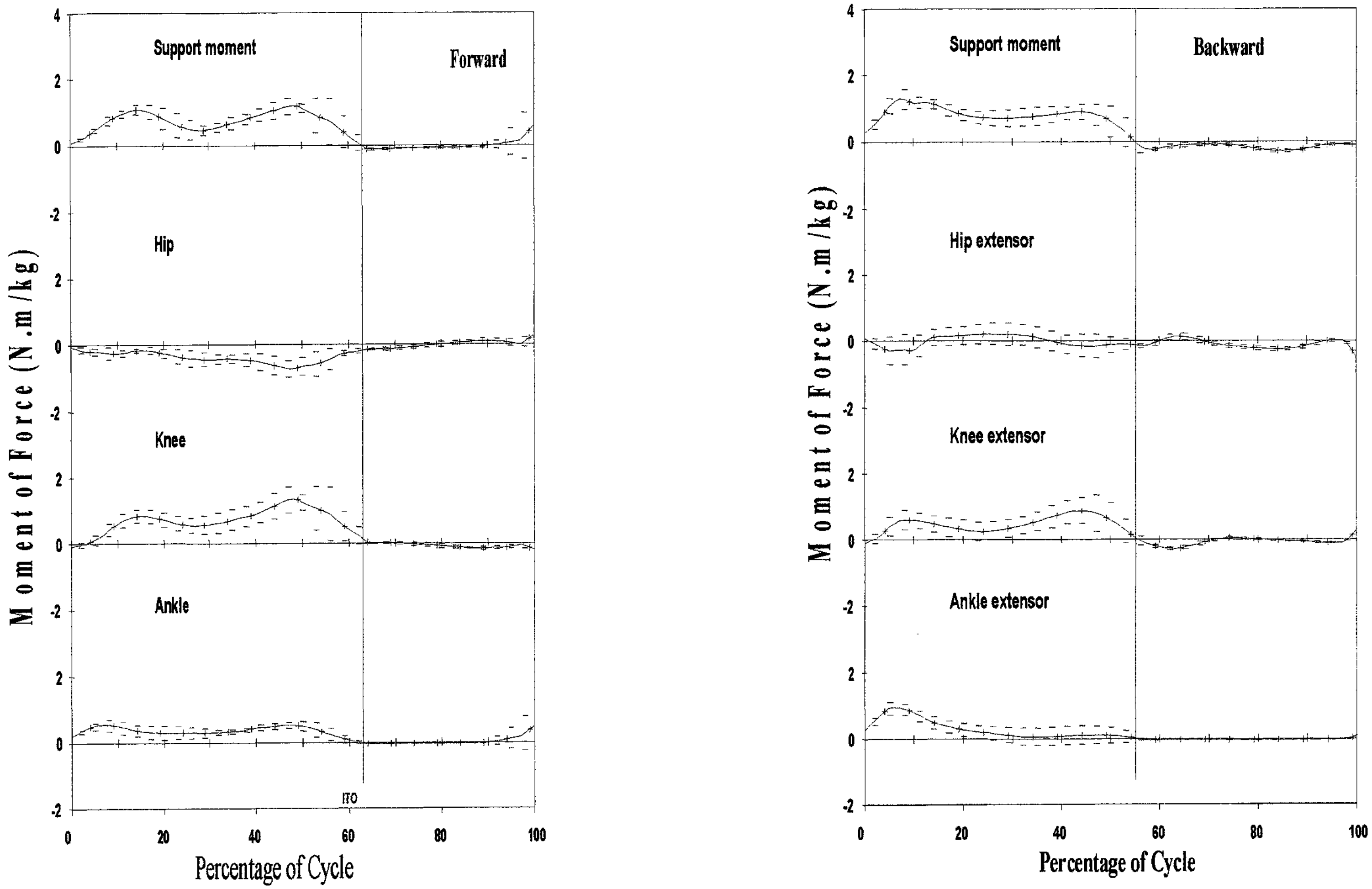


Figure 21. **Support moments of GE while descending stair forward or backward at ankle, knee and hip**

Minimal hip flexor and extensor activity were required to bring the knee forward and down and throughout the motion, the knee itself needed minimal flexor and extensor concentric contractions. When compared to level walking, the forces acting at the knee were smaller than the ones obtained in stair descent (Winter, 1991). The hip acted with minimal moments and powers suggesting a stabilizing activity only.

Walking and stair descent moment powers

The differences between walking and stair descent were by far larger when looking at the moment powers of the ankle where no initial dorsiflexor phase occurred but an earlier and larger eccentric plantar flexor phase (SA0) occurred. This phase dissipated energy while the ankle dorsiflexed after its initial plantar flexed landing position. It represents the most important energy sink and resulted in 80% to 85% of the energy dissipated during the entire gait cycle. In walking, the single most important energy generation phase was A2, which represents 80% - 85% of that generated during the entire gait cycle (Winter, 1991). Whereas, in stair descent, the corresponding plantar flexor concentric power (SK2) was relatively small.

The knee had almost no concentric extensor phase (SK2) in forward stair descent. The leg seems to require a lighter extension just enough to reach the step. In contrast with walking, the main energy dissipation occurred at midstance (SK3) where the weight acceptance occurred with an eccentric extensor contraction. Thus, forward stairs descent demanded a lot more than walking and required stronger lower extremity moments of force. The capacity to sustain such moments of forces at knee level might be too much for someone tired, weak or injured.

The hip had minimal moment powers (Fig. 20) with levels of activity similar to slow walking and normal walking where the power levels are very low (Winter, 1991). In forward stair descent (Fig. 21), the hip maintain balance and contribute little (Joseph and Watson, 1967) to the actual work of lowering the body (McFadyen and Winter, 1988). It acted as a stabilizer to lower the body (Andriacchi et al., 1980) maintaining balance.

Backward Descent

In all subjects' trials, we observed an increase in cycle duration (backward 1.349 s. against forward 1.134 s.) ($P<0.03$). On the other hand, the slowing down forward descent did not produce similar effects as the backward descent. In fact, going down slower, when descending forward, didn't seem to diminish the larger support moments' variability observed in all trials. There was no significant difference with moment powers between forward descent and slow forward descent at ankle ($P<0.90$) and knee ($P<0.71$) level. If injured, the pace of descent might not be enough to reduce the larger support moment variability and the moment powers at ankle and knee level.

In all trials, the results of backward descent showed a foot position further away the tip edge of the step ($P<0.001$) compared to both forward descents. Because the foot touches down farther from the edge of the step the chances of slipping off the edge are reduce. If wearing shoes (around 30 cm long) minimal space is left to reach the edge in a forward descent.

Another big difference in the backward stair descent was the reduced variability in the second peak of the support moments. The subjects were more consistent when loading occurred at the ankle and knee levels. In backward stairs descent we observed larger support moments with similar double peaks as walking and with significantly lower mean peak powers at the knee level ($P=0.005$) where larger activity was found when descending forward (Joseph & Watson, 1967; Andriacchi et al., 1980; McFadyen & Winter, 1988; Livingston et al., 1991; Wyatt et al., 1999; Startzell et al., 2000). The negative extensor power required was less when reaching the one leg support before the swing. At the ankle level, the plantar flexor moments reduced and the extensor of the knee moments increased both with less variability. The hip support moments were still smaller but with little power.

Backward Stair Descent Moment Powers

When looking at the ankle moment powers a larger eccentric power peak (SA1) (Fig. 15) happened during weight acceptance. This larger but non-significant increase may be the cause of the later and smaller knee dissipation. If the ankle dissipated a larger portion of the energy than a smaller portion remains to be dissipated by the knee.

In the last part of the stance phase, the plantar flexors generated a smaller SA3 peak push-off. The reason is due to lesser demand to clear the tip edge of the step. This action resembled more a gentle release than a push-off. The ankle needed just a little push to clear the step edge because the work itself was mainly performed by the knee flexor concentric phase (SK4) (Fig. 17).

The extensor concentric work at the knee level (SK2) was slightly larger to prepare the lower leg for contact (Fig. 17). This activity was more like a gentle reaching motion. The significantly (P=0.005) reduced peak extensor eccentric power (SK3) showed a lesser demand at the knee level compared to forward stair descent. This was the most important difference between forward and backward descent. If you add up the large energy dissipation with the large knee flexor moment it results into a three times (Andriacchi et al., 1980) larger flexion moment than the one generate during walking. The chances of slipping or collapsing may increase when using forward descent. The solution could in fact be the use of the backward descent, which required a smaller knee moment and power.

The grand ensemble looked very similar to that of subject JC. A larger peak eccentric power (SA1) (Fig. 15) showed increased work at the ankle level and a reduced peak extensor eccentric power (SK3) (Fig. 17) at the knee level. This variation represents a work diminution performed at this level. Like JC, the GE backward stair descent showed smaller support moments variability in the second peak.

The slowing down effect of backing down the stairs may help the subject to grab the railing providing better support. If tripping occurs, the railing will slow down the fall and a person will go down and be closer to the step causing less vertical impact. Because of the proximity of the step, a person with visual impairment should have a better visual perception due to proximity of the steps than going forward where they are further away. The main concern is the unconventional nature of the backward descent. This may affect compliance.

Prescribing a backward descent does not only apply to people with disabilities or frailties. It may be appropriate during pregnancy or when muscles are fatigued or sore from exercise. The backward descent approach provides an alternative which may benefit certain groups within the general population.

Chapter 5

SUMMARY

Descending stairs is a task that increases loading at the joints of the lower extremities (Andriacchi et al., 1980) as compared to walking (McFadyen and Winter, 1988), which may cause both discomfort and difficulty in completing the task of stair descent. The general aim of this study was to compare and contrast the kinematics and kinetics of forward and backward stair descent as a means of assessing the relative demands of each task. The specific objectives were to compare the support moment and moment powers of the lower limb joints while descending stairs in both types of scenario and secondly, perform an analysis of foot cadence, and foot position to determine which method was more likely to reduce the risk of a fall. Because little information exists, data needed to be collected that can be extrapolated to the normal population. A sample size of 10 subjects (6 men and 4 women) with heights of: 1.65 m ± 3 cm, 1.73 m ± 3 cm, and 1.80 m ± 3 cm. All subjects were between the ages of 20 and 35 with no previous history of lower extremity joint problems. Seven markers were placed on both sides of the subject to distinguish the body segments of the lower limb. Two high-speed Panasonic cameras and three Kistler forces plates were used to collect kinematics and kinetics data. One platform's data was analyzed with the Biomech Motion Analysis Software (http://www.health.uottawa.ca/biomech/csb/software/biomech.htm) that calculated the inverse dynamics for each joint and combined the kinematics and kinetic data. A comparison between walking and stair descent was performed and between forward and backward descent. Furthermore, an analysis was made to determine the foot position and cadence differences between the types of descent. The results showed an increase in stance phase (65

to 70%) and a reduction in swing phase (35 to 30%) compared to walking. Larger double peak support moments with reduced ankle plantar flexor and increased knee extensor were found. The hip moments were highly variable but produced little power. The backward descent showed the centres of pressure of the ground reaction forces farther from the step edge than forward descent ($P<0.001$) on all trials. There was also a significantly reduced knee peak extensor power ($P=0.005$) with less variability compared to the slow forward descent. The ankle plantar flexor moments had larger peak eccentric powers and smaller push-off powers. The results suggested that higher level of joint kinetics were required for both forward and backward descent compared with level walking but backward descent was less demanding at the knee level than forward descent. The main power dissipation was eccentric in both cases but backward descent had a lesser extensor eccentric peak power at the knee level providing lesser demanding work at this joint. One should consider a backward descent for people weaker or injured at the knee. The better foot positioning, slower cadence and lesser moment power at knee level present a scenario with lesser demand one could achieve with less fear of slipping and falling when descending stairs.

CONCLUSION

Based on the statistical results obtained the following conclusion are warranted. The analysis undertaken in this study showed that using a backward stair descent was an important approach one should consider if unable to proceed in the usual forward fashion. Both forward and backward descent required higher levels of joint kinetics than walking but backward descent was less demanding at the knee level ($P=0.005$) than forward descent. The foot positioning was more posterior ($P<0.001$) to the edge of the step reducing the chance for slipping over the edge. Descending stair backwards could be an alternative if injured or weak at knee level or if unable to access stairs in usual fashion forwards direction.

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INTERNET LINK

1. http://www.health.uottawa.ca/biomech/csb/software/biomech.htm

APPENDICES

APPENDIX 1

Université d'Ottawa
University of Ottawa

HEALTH SCIENCES AND SCIENCE
RESEARCH ETHICS BOARD

CERTIFICATE OF ETHICAL APPROVAL

This is to certify that the University of Ottawa Health Sciences and Science Research Ethics Board has examined the application for ethical approval for the research project "The control of stair descent in healthy young and healthy aging adults: Comparing the effects of speed and amount of lower limb weight bearing on forward and backward stair descent performance. (File H06-02-02) submitted by Lucie Pelland, assistant professor. The Board found that this research project met appropriate ethical standards as outlined in the Tri-Council Policy Statement and in the Procedures of the University of Ottawa Research Ethics Boards, and accordingly gave it a Category 1a (approval). This certification is valid for one year from the date indicated below.

____________________________ September 26, 2002

Catherine Lesage Date
Protocol Officer for Ethics in Research,
For the Chairperson of the Health Sciences and Science REB
Daniel Lagarec

APPENDIX 2

Université d'Ottawa
University of Ottawa

DOCUMENT D'INFORMATION ET
FORMULAIRE DE CONSENTEMENT

Analyse biomécanique de la descente d'escaliers
chez une population saine jeune et âgée :
Comparaison de deux méthodes de descente,
une d'avant et l'autre à reculons à différentes vitesses

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Énoncé de l'invitation

Vous êtes invité à participer dans un projet de recherche qui est un effort collaboré entre les chercheurs de l'École des Sciences de réadaptation (programme de Physiothérapie) ainsi que l'École d'Activité Physique de l'Université d'Ottawa. Ce projet de recherche est dirigé par les chercheurs mentionnés ci-haut et sous la supervision de Lucie Pelland, Ph.D., professeur adjointe au programme de physiothérapie à l'Université d'Ottawa. Nous apprécions grandement votre intérêt porté à notre travail.

INTENTIONS DE L'ÉTUDE

Le but de cette étude est d'évaluer les différences dans la performance de la descente d'escaliers chez une population saine de jeunes adultes et d'adultes vieillisants. Nous sommes aussi intéressés à évaluer les différences de stratégies neuromotrices qui sont utilisées par ces deux groupes pour modifier le mouvement de la jambe afin d'adapter leur descente d'escalier à une augmentation de la vitesse de descente tout en maintenant l'équilibre postural. La capacité de maintenir l'équilibre lors de la descente d'escalier est un pré-requis permettant des déplacements de façon plus sécuritaire et permet le maintien d'une certaine forme d'indépendance à la maison et en milieu communautaire. L'information acquise lors de cette étude nous fournira une meilleure compréhension des facteurs qui contribuent aux risques de chutes lors de la descente d'escaliers chez les personnes âgées.

VOTRE PARTICIPATION À CETTE ÉTUDE IMPLIQUE:

1. Obtenir un consentement informé avant la session expérimentale.

2. Compléter un bref questionnaire sur votre histoire médicale.

3. Préparation de la collecte des données selon les procédures suivantes :

    a) Mesure de l'amplitude articulaire de vos membres inférieurs ainsi que de la colonne lombo-sacrée.

    b) Mesure de vos habiletés d'équilibre utilisant trois évaluations qui sont fréquemment utilisées en milieu clinique - L'échelle d'équilibre de Berg, le « Functional Reach Test » et le temps d'appui unipodal avec les yeux ouverts et fermés.

    c) Port de vêtements noirs et une paire de soulier avec semelle de caoutchouc qui vous seront fournis par le laboratoire de Biomécanique.

    d) Des marqueurs réfléchissants auto-collants seront fixés à votre épaule, à votre hanche, à votre genou, à votre cheville et à votre pied. Ceci nous permettra d'enregistrer les données de position durant votre descente. Les données seront analysées avec le « ARIEL Performance Analysis System ».

4. Exécuter les tâches suivantes pour l'obtention des données :

Pour l'expérience, nous allons utiliser un escalier de 3 marches fabriqué dans le laboratoire de biomécanique à l'École des sciences de l'activité physique (Pavillon Monpetit, Salle 309). Trois plates-formes de force sont intégrées sur les marches (i.e. une intégrée dans le sol, une sur la première marche et une dernière sur la deuxième). Ces plates-formes de forces nous permettrons de mesurer la force que vous appliquerez sur vos membres inférieurs lors de la descente d'escalier.

Vous recevrez des directives sur la façon de descendre l'escalier par-devant et à reculons. Vous pourrez pratiquer jusqu'à ce que vous vous sentiez confortable avec l'exécution de la tâche expérimentale. Un assistant de recherche sera près de vous en tout temps pour vous venir en aide si vous perdez l'équilibre.

Nous vous demanderons d'exécuter 5 descentes d'escaliers en suivant les conditions expérimentales énoncées ci-dessous :

a) Descente d'escalier par en avant à votre rythme préféré. Nous mesurerons votre vitesse de descente à l'aide de métronome électrique.

b) Descente d'escalier de reculons à votre rythme préféré. Encore une fois, nous mesurerons votre vitesse de descente à l'aide de métronome électrique.

c) Descente d'escalier par en avant à la vitesse de votre descente à reculons.

Notez Bien: La session expérimentale aura une durée approximative de 60 minutes et vous aurez à exécuter un total de 20 essais. Des périodes de repos vous seront permises au besoin.

Risques et inconforts

La nature répétitive de la tâche peut occasionner un endolorissement musculaire ainsi que de la douleur à la hanche, au genou ou à la cheville. Par contre, comme des périodes de repos seront permises au besoin, les effets secondaires devraient être minimes. Il existe aussi la possibilité d'entorse à la cheville ou de chute causée par un faux pas durant la descente d'escalier. Un assistant de recherche sera présent en tout temps pour vous assister. Veuillez noter que plusieurs autres études sur la descente d'escalier furent réalisées chez les enfants ainsi que chez les adultes sans aucune blessure. Vous allez peut être vous sentir un peu essoufflé lors de la monté et de la descente d'escalier. N'hésitez pas de communiquer tout inconforts au chercheur; vous aurez la possibilité de vous arrêter pour vous reposer si vous ressentez certains malaises ou inconforts. Il y a également possibilité de crainte lors des descentes rapides et de reculons. Afin de bien documenter vos incertitudes face à la tâche, nous vous demanderons périodiquement d'inscrire votre niveau de crainte sur une échelle analogue visuelle de 'aucune crainte' à 'extrême crainte'.

Inscrire un 'X' pour indiquer votre niveau de crainte

____Aucune

crainte Extrême crainte

(qui vous empêche de continuer la tâche expérimentale)

Avantages

Il n'y a aucun gain personnel qui découle de votre participation à cette étude. Cependant, l'information que nous obtiendrons nous servira à comprendre le maintien de l'équilibre lorsqu'une personne descend un escalier. Nous espérons ainsi identifier plus efficacement les limites de sécurité chez un client.

Anonymat et confidentialité

Votre anonymat comme participant sera maintenu en tout temps en utilisant un numéro d'identification au lieu de vos initiales lors de l'analyse des données et de la publication des résultats de cette étude. Aucune identification personnelle ne sera utilisée dans les publications de cette étude. Toutes les informations enregistrées seront gardées à l'Université d'Ottawa pour la durée de l'étude et pour une période de 5 ans après la fin de l'étude.

EN CAS D'URGENCE

En cas de chute ou de troubles cardio-respiratoires durant la session d'enregistrement, les chercheurs s'assureront que vous êtes en sécurité et confortable. Le service d'urgence de l'Université d'Ottawa sera appelé immédiatement à partir du laboratoire et vous portera assistance dans un bref délai, ainsi que de communiquer avec le service 911 de la région d'Ottawa si nécessaire.

ENQUÊTE AU SUJET DE CETTE ÉTUDE

Ce projet de recherche a été approuvé par le Comité d'éthique en recherche à l'Université d'Ottawa. Pour des questions concernant l'approbation d'éthique de cette étude, vous pouvez contacter *Ms. Catherine Lesage* au (613) 562-5800, poste 5287 (courriel : cleasge@uottawa.ca), Officier du protocole pour l'éthique en recherche à l'Université d'Ottawa. Si vous avez besoin de plus amples renseignements au sujet de l'étude (procédures expérimentales ou autres détails), n'hésitez pas à contacter les responsable *François G. D.Beaulieu, le Dr. Lucie Pelland ou le Dr. Gordon Robertson* aux numéros ou aux adresses mentionnées au début de ce document. Une copie de ce formulaire vous sera fournie avant la fin de la session.

APPENDIX 3

Université d'Ottawa
University of Ottawa

FORMULE DE CONSENTEMENT

JE, ______________________________, ACCEPTE VOLONTAIREMENT DE PARTICIPER À L'ÉTUDE MONTIONNÉE CI-HAUT AU SUJET DU CONTRÔLE BIOMÉCANIQUE DE LA DESCENTE D'ESCALIER PAR EN AVANT ET À RECULONS.

J'AI REÇU ET LU UNE DESCRIPTION DÉTAILLÉE DU PROTOCOLE EXPÉRIMENTAL. JE SUIS COMPLÈTEMENT SATISFAIT AVEC LES EXPLICATIONS QUI M'ONT ÉTÉ FOURNIES AU SUJET DE LA NATURE DE CE PROJET DE RECHERCHE, INCLUANT LES RISQUES ET INCONFORTS POSSIBLES RELIÉS À MA PARTICIPATION À CETTE ÉTUDE.

JE SUIS AU COURANT QUE JE POSSÈDE LE DROIT DE RETIRER MON CONSENTEMENT ET MA PARTICIPATION EN TOUT TEMPS SANS AUCUN PRÉJUDICE.

SIGNATURES

Participant/e

____

(signature) (Nom imprimé)

Témoin

____

(signature) (Nom imprimé)

Date: ________________________

APPENDIX 4

QUESTIONNAIRE POUR INFORMATION SUR LE SUJET ET ANTÉCÉDENTS MÉDICAUX

Identification du sujet

Nom: ____________________________ Code d'identification: ________

Âge: ________ ans Sexe: M or F Numéro de téléphone: ______________

Antécédents médicaux

1. Vous êtes-vous récemment plaint de douleur aux membres inférieurs?

   Oui ou Non

   Si oui, spécifiez

   ____

   a) Avez-vous déjà subi des blessures sévères? Oui ou Non

      Si oui, spécifiez

      ____

2. Avez-vous déjà été affecté(e) par les troubles suivants?
   a) Troubles articulaires Oui ou Non

      Si oui, spécifiez

      ____

   b) Troubles visuels Oui ou Non

      Si oui, spécifiez

      ____

   c) Troubles vestibulaires Oui ou Non

      Si oui, spécifiez

      ____

   d) Troubles épileptiques Oui ou Non

      Si oui, spécifiez

      ____

e) Avez-vous déjà subi une ou des interventions chirurgicales? Oui ou Non

Si oui, spécifiez

____

3. Prenez-vous des médicaments? Oui ou Non

Si oui, spécifiez

____

4. Êtes-vous déjà tombé? Oui ou Non

Si oui, spécifiez

____

5. Souffrez-vous d'autres conditions médicales qui devraient être mentionnées?

Oui ou Non

Si oui, spécifiez ______________________