RELATIONSHIP BETWEEN GAIT PATTERN AND SHOCK ABSORPTION CAPACITY

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INTRODUCTION

Musculoskeletal conditions are the main disabling conditions worldwide[1] (Figure 1). The number of treatment sessions in physical therapy for these pathologies vary greatly depending on patients' characteristics. However, there is an increase of patients suffering from chronic musculoskeletal pain in practice. It is also observed that treatments are often local and, although effective in relieving pain in the short-term, they are ineffective in the long-term[2].

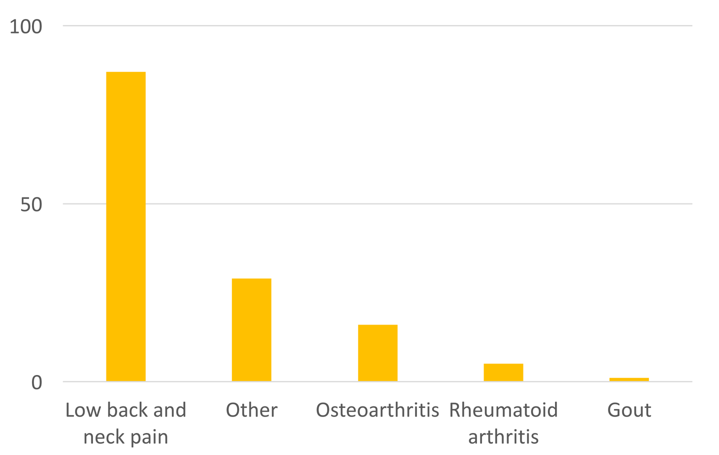

Figure 1: Most prevalent musculoskeletal conditions in 2016 and the corresponding years lived with disability[9].

The maximum amount of shock that the body structures can absorb is defined as the shock absorption (SA) capacity. When it is not optimal, it plays a role in the development of these conditions[3].

Measuring it with accelerometry in clinical practice would allow health care providers to detect suboptimal shock absorption early enough to provide a preventive treatment[4]. Accelerometry is also an effective and reliable tool to analyse gait patterns and it is cheaper to implement compared to 3D gait analysis[5].

As most studies related to kinematics and shock absorption focussed on sports-related movements, there is a lack of knowledge about the relationship between kinematics and shock absorption during walking.

A correlation has been found between the foot progression angle (FPA) (Figure 2) and the tibial torsion during walking[6]. As tibial external rotation causes a lateral shift of the ground reaction force (GRF), it affects the kinematics of the hip and knee during gait, which have a major role in shock absorption[7]. Since the GRF has been related to tibial acceleration[8], **the aim of this study is to investigate the strength of the correlation between the FPA and the SA capacity of the leg in healthy individuals during walking**.

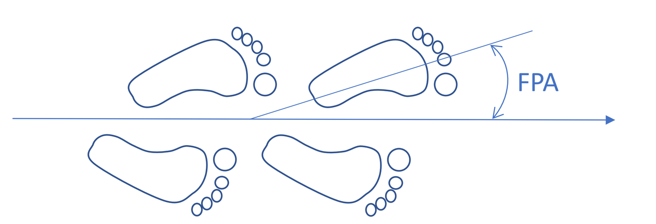

Figure 2: The FPA or "toe-out" angle represents the angle formed by the intersection of the line of progression of the foot and the line extending from the center of the heel through the second metatarsal during gait[10].

METHOD: Cross-sectional study

Participants recruited via email were students at Fontys University of Applied Sciences and met the following criteria:

Inclusion criteria
- >16 and <50 years old
- BMI < 29.9 kg/m²

Exclusion criteria
- Orthopaedic pathologies
- Overpronated or oversupinated feet
- Mental illness

Measurement tools
- Trigno Avanti EMG System (Delsys Inc., MA, USA)
- 3 accelerometers coupled with gyroscopes
- Data acquisition: EMGworks (Delsys Inc., MA, USA)
- Data exportation: MATLAB (MathWorks, MA, USA)

Protocol
- Sensors placed with double sided tape: one sensor on the right malleolus, one on the left malleolus and one on the sacrum
- Familiarising time for 5 minutes
- Data was recording barefoot and participants were instructed to consecutively:
  1) Stand upright and still for 5 seconds
  2) Walk at a comfortable pace in a straight line for 20 steps
  3) Stop and stand upright and still for 5 seconds

Outcome measures
- **FPA** was calculated as the angular velocity of the tibia in the transverse plane between neutral position (participant standing still with feet parallel) and position at heel strike. It was obtained thanks to the gyroscopes placed at the malleoli level and is expressed in degrees
- **Shock reduction (SR)** was calculated as the difference between peak tibial acceleration and peak sacrum acceleration and is expressed in m/s² (Table 1)
- **Shock absorption (SA)** represents the difference between peak tibial acceleration and peak sacrum acceleration relative to the peak tibial acceleration and is expressed in percentage (Table 1)

Statistical analysis
- IBM SPSS Statistics 23 (IMB, Armonk, NY, USA)
- Normality assumed (no difference in the outcome with the use of non-parametric tests)
- Pearson correlation test between FPA and SA
- Additional analyses
  - Differences between genders
  - Correlation between SA and age, weight and BMI

Table 1: Calculation of the outcome measures

Variables	Formula
SR (m/s²)	SR = peak tibial acc. − peak sacral acc.
SA (%)	$SA = \left(\frac{\text{peak tibial acc.} - \text{peak sacral acc.}}{\text{peak tibial acc.}}\right) \times 100$

RESULTS

Table 2: Participants characteristics

Variable	Mean ± SD
Gender	10 males (45.5%) 12 females (54.5%)
Age (years)	23 ± 2
Height (cm)	173.4 ± 6.9
Weight (kg)	69.2 ± 9.3
Body Mass Index (kg/m²)	23 ± 2.2

Table 3: Comparisons of the variables between sides and their variation within the sample

Variable	Mean ± standard deviation	Range (min – max)	*p*
Foot progression angle (in degrees)			
Right	6.5 ± 9.6	40.2 (-8.3 – 31.9)	
Left	8.8 ± 7.3	29.5 (-5.7 – 23.8)	
Absolute difference between left and right	6.0 ± 3.5	14.2 (1.2 – 15.4)	0.12
Shock absorption (in percentage)			
Right	91.3 ± 2.8	9.7 (85 – 94.8)	
Left	91.3 ± 3.5	12.5 (82.4 – 94.8)	
Absolute difference between left and right	1.5 ± 1.4	4.9 (0.1 – 5)	0.99
Shock reduction (in m/s²)			
Right	8.1 ± 2.2	8.2 (4.8 – 13)	
Left	8.0 ± 1.8	7.1 (5.4 – 12.5)	
Absolute difference between left and right	1.0 ± 1.0	3.2 (0.1 – 3.3)	0.66

Table 4: Negligible to low positive correlations between variables

Variables	*r*	Classification of the correlation[11]
FPA and SA right leg	0.31	Low
FPA and SA left leg	0.33	Low
Age and SA right leg	0.36	Low
Weight and SA right leg	0.28	Negligible
BMI and SA right leg	0.34	Low

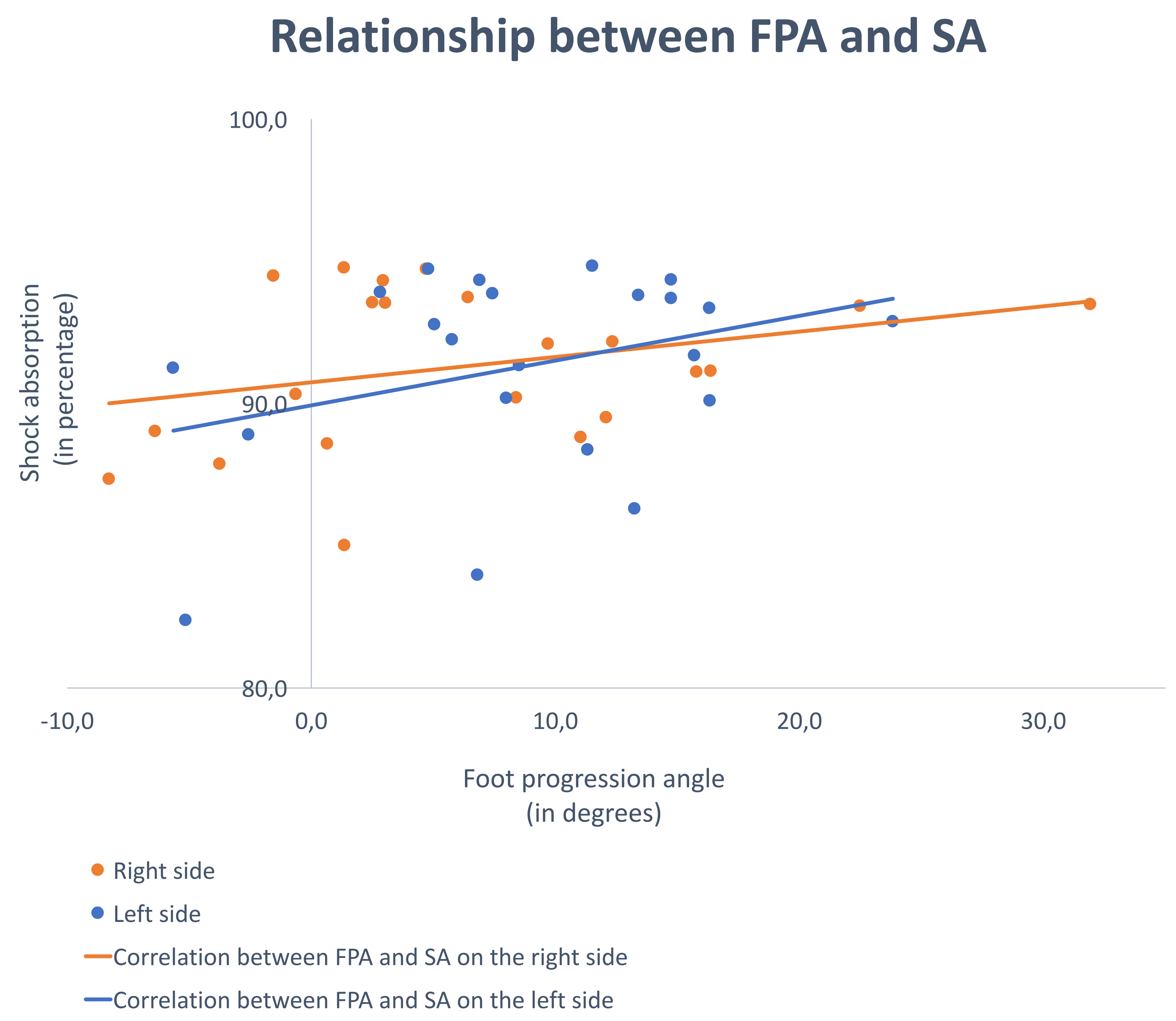

Figure 3: Low positive correlation between the FPA and SA in the leg (r_{right} = .31; r_{left} = .33)

INTERPRETATION

The goal of this study was to investigate the strength of the relationship between the foot progression angle and the shock absorption capacity of the leg in healthy individuals. A low positive correlation was found (Figure 3), which means that there is no strong evidence to suggest a relationship between both variables.

The results of this research are consistent with previous studies[6,12]. Most of the shock is absorbed in the leg (Table 3) to protect the visual and vestibular systems from high accelerations in postural control and walking[4]. However, the low correlation found between FPA and SA is surprising. Indeed, FPA is strongly correlated to tibial torsion[6] and previous studies found high correlations between tibial torsion and gait kinematics related to shock absorption, such as knee joint angle and knee adduction moment[13,14]. This divergence can be explained by the fact that the FPA can be due to hip external rotation, tibial external rotation, tibial torsion or foot rotation but it was not feasible for us to assess the participants to distinguish between them.

Previous studies suggested the use of individualised gait kinematics in order to reach a constant SA[4,15]. This is coherent with our findings as the variation within the population was higher in the FPA than in the SA (Table 3). Therefore, it can be hypothesized that the adoption of an increased FPA is an adaptive mechanism in order to protect another part of the body by keeping a steady SA. To investigate this theory, future studies should compare different kinematics strategies within the same individual through intervention methods. The fact that the correlation is low can suggest that a change in FPA is not the only strategy used but rather part of a combination of kinematics changes in the lower limbs.

If individuals present with unique altered biomechanics to maintain a constant SA, suboptimal SA in overweight people due to joint overloading could also lead to compensations. This could explain why we found only negligible to low positive correlations between SA and weight and BMI (Table 4), despite these variables being related to joint overloading[16].

These findings are highly relevant for clinical practice as screening for gait deviations could help to identify underlying musculoskeletal issues, even if the SA is within normal ranges. Indeed, prevention must have a major role in physical therapy treatments and future researches should focus on a further understanding of SA mechanisms as it will allow health care providers to set up more efficient preventive treatments.

Our research encountered a few limitations that should be taken into account in the future:
- No evidence yet to support the measurement protocol of FPA during gait using accelerometry
- Lack of variability within participant characteristics (Table 2)
- The reason for changes in FPA was not checked

CONCLUSION

Our study found a low positive correlation between the foot progression angle and the shock absorption in the leg of healthy individuals. We noticed a constant amount of shock absorbed between people despite a high variation in foot progression angles. Our hypothesis is that individuals alter their gait biomechanics in order to reach the same amount of shock absorption to protect the head, more specifically the visual and vestibular systems, from high accelerations. However, the low variability in our participants' characteristics prevents us from drawing generalizable conclusions and further studies are needed to understand the role of individualised kinematics adaptations in the optimisation of the shock absorption.

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