035 SOME OF THE FACTORS INFLUENCING THE HEEL PAD COMPRESSIBILITY INDEX (HPCI)

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Abstract: The human heel pad is a complex structure that features non-linear visco-elastic characteristics as the majority of the human soft tissues. The biomechanical aspects of the heel pad are still under investigation and the influence of subject factors such as age, weight, gender, height, race, and body activity have been reported. The aim of this paper is to study the literature in order to identify the influence of subject factors and diseases on the heel pad compressibility index.

I. Introduction

The human heel pad is a complex structure that features non-linear visco-elastic characteristics as the majority of the human soft tissues. It acts as an efficient shock absorber reducing the impact forces during gait. Trauma to the heel pad and/or diseases may cause the “destruction” of its intricate septation with resulting permanent damage of its shock absorbency capability.

The biomechanical aspects of the heel pad are still under investigation especially when a disorder is present. When measuring a biomechanical parameter of the heel pad for the purpose of diagnosis, the normal range of this parameter must be known as well as the variation with factors such as age, weight, gender, height, etc [1], [2], [3]. The influence of any single subject factor may, however, only be revealed if all other factors are controlled. As a consequence, it is possible that an effect of a given factor may be overlooked or falsely detected if the whole range of factors is not taken into account. Uncontrolled factors thus become confounding factors. We therefore found it important to review the literature in order to define factors with influence on heel pad compressibility index. The present study concentrates on the variation of the heel pad compressibility index (HPCI).

The aims of this literature review are to identify subject factors influencing on heel pad compressibility index and investigate whether consistent conclusions may be drawn in order to recommend which subject factors need to be controlled in future trials.

II. Method

Literature searches have been carried out in the bibliographic databases Inspec, EMBASE via Ovid, Medline via Pubmed, and Web of Science ultimo April 2009.

The following keywords were used: heel pad thickness, heel pad compressibility, heel pad-elderly/diabetes/heel pain, heel pad elasticity

Thirty nine papers were identified. Concentrating on studies only dealing with *in vivo* measurements of the heel pad compressibility index, and subjects/patients at least 18 years of age resulted in 10 papers. Each identified paper was scanned for missing papers in the list of reference. Within the 10 selected papers, 16 studies were performed.

In order to establish whether or not the subject factors are controlled within each study, a difference of ±5 years for the age, ±5 kg for the weight, and ±5 cm for the height between the groups under investigation is considered acceptable.

The studies were divided into two main groups depending on whether a control group was present or not. Subsequently both groups were divided into subgroups, as illustrated in Table 1.

Table 2: Increase of HPCI as a function of the subject factors

Studies <u>without</u> control group	<u>A) Normal conditions</u>: normal healthy subjects are investigated for the influence of age, weight, (height), and physical activity.
	<u>B) Heel pain</u>: subjects suffering of heel pain are investigated on the influence of age and weight
Studies <u>with</u> control group	<u>C) Diseased conditions</u>: subjects with diseases/trauma such as diabetes and heel pain are investigated

III. Definition

A simple representation of the heel pad and the calcaneum bone, with or without the application of a load, is shown in Figure 1. Specifically, F is the load applied on the skin of the heel pad; Y_0 is the starting point located on the lowest part of the plantar tuberosity of the calcaneum; Y_L is the value of thickness when a load F is applied (loaded condition); Y_U is the value of the heel pad thickness when a load F is not applied (unloaded condition).

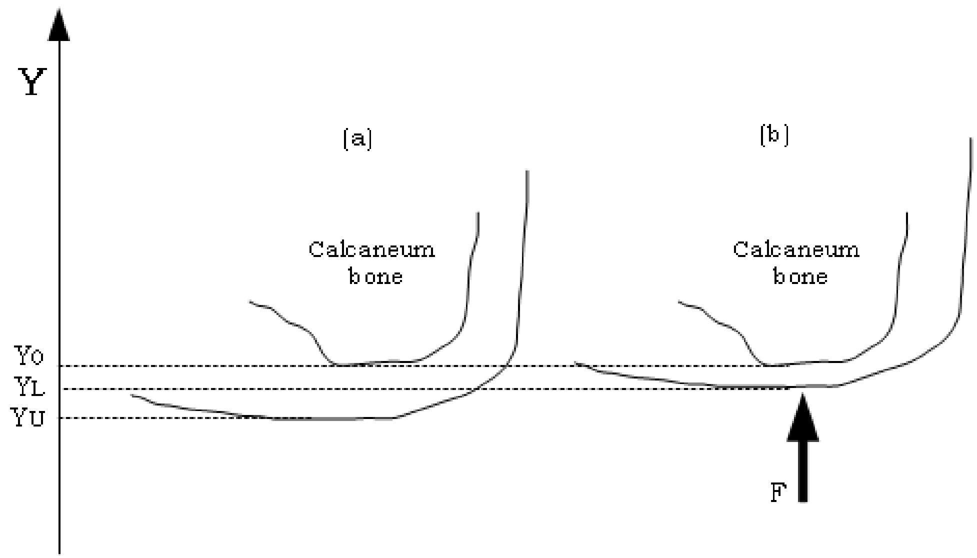

Figure 1: Schematic illustration of unloaded (a) and loaded (b) heel pad

The ***<u>Unloaded Heel Pad Thickness (UHPT)</u>*** is defined as:

$$UHPT = YU - Y0 \quad (1)$$

The ***<u>Loaded Heel Pad Thickness (LHPT)</u>*** is defined as:

$$LHPT = YL - Y0 \quad (2)$$

Both UHPT and LHPT were measured by using either lateral radiography or ultrasonic imaging of the region from skin to bone.

The ***<u>Heel Pad Compressibility Index (HPCI)</u>*** is defined as the ratio of the heel pad thickness in loaded conditions to unloaded positions. It is expressed as:

$$HPCI = (LHPT/UHPT)*100 \quad [\%] \quad (3)$$

The HPCI expresses the ability of the heel pad to be compressed. If *HPCI* is close to 100%, then the elasticity of the heel pad approaches 0 [2], [3]. When loads are applied sequentially, the maximum load (F_{max}) is used in the calculation of the loaded heel pad thickness [1], [4], [5].

IV. Results

Each of the papers that met the inclusion criteria were considered with respect to the HPCI (described in the Method section), and to a possible control of the subject factors.

The results are shown in Table 2 and Table 3. The body of Table 2 shows the tendency of HPCI for each study considered. The tendency is represented by a symbol that shows a statistical significant (p-value ≤ 0.05) increase or decrease of HPCI (↑, ↓), or a not-statistically-significant change (≈) when the subject factor in the leftmost column is increasing.

The symbol is followed by square brackets containing information about the study size. The first number identifies the paper in the list of reference, while the remaining numbers indicate the amount of heels under investigation. E.g. in [8, 2*120 + 102#], 8 indicates the reference number of the paper. A total of 342 heel pads were investigated: 2*120 from subjects having both heel pads analyzed, plus 120 heel pads from a number of subjects were one or two heel pads were analyzed. Especially when either unilateral and bilateral heel pain or fractured heels are investigated within the same study, the number of the analyzed heel pads could not be the same as the number of patients.

The following tables reveal tendencies instead of absolute values; since the methodologies used in the selected papers vary, absolute values cannot be compared.

Table 2: Increase of HPCI as a function of the subject factors

	Subject Factors \ **Mechanical Parameter**	**Heel Pad Compressibility Index (HPCI) [%]**
A) Normal conditions	**Age**	↑[1,65#] ↑[2,2*200] ↑[3,2*400] ↑[8, 2*120]
	Weight	↑[3,2*400] ↑[8, 2*120]
	Physical activity (low vs. high activity)	≈ [6, 2*110]
B) Heel Pain	**Age**	↑[10,67#]
	Weight	↑[10,67#]
C) Diseases vs. Normal	**Diabetes**	↑[7,38#] ≈[4,2*21+14#+2*20]
	Heel pain	↑[2,2*200+70#] ↑[7,38#] ≈[8, 2*120+102#] ≈[9, 2*47+94#] ≈[5,2*20]

≈ No statistical significant difference (p>0.05), ↑ or ↓ statistical significant difference (p≤0.05).

Arrow [Ref, N] = tendency [reference number, number of heel pad under investigation]

Table 3 shows results for the heel pad compressibility index pointing out which studies have been controlling the subject factors. Specifically, the table is made of two parts each one divided into three columns (where tendencies are shown). The first part of the table contains all the studies considered (joining together group A and B), while the second part contains only the studies controlling subject factors.

Table 3: Overview of tendencies found from the selected studies.

Subject factors	All studies			Studies controlling subject factors		
	↑	≈	↓	↑	≈	↓
Age (normal and heel pain)	[1] [2] [3] [8] [10]			[3] [8]		
Weight (normal and heel pain)	[3] [8]	[10]		[8]		
Physical activity (normal)		[6]				
Diabetes (disease vs. normal)	[7]	[4]			[4]	
Heel pain (disease vs. normal)	[2] [7]	[8][9][5]		[7]	[8][5]	

≈ No statistical significant difference ($p>0.05$); ↑ or ↓ statistical significant difference ($p\leq 0.05$); [Ref] = [reference number]

V. Discussion and Conclusions

As seen from Table 3, no study found a decrease in HPCI.

- 6 studies investigating age and weight in normal subjects showed that HPCI increases with increasing age and weight. Of these 6 studies, 3 were controlling the subject factors.

- 2 uncontrolled studies investigated age and weight in subjects with heel pain. HPCI still increases with age and weight.

- 1 uncontrolled study investigating physical activity in normal subjects showed that HPCI does not change.

We conclude that studies on HPCI must control for age and weight when investigating possible effects on other factors such as e.g. various diseases, race, gender, nationality. No studies investigated the effect of height on HPCI. It is not surprising that it might have an effect. Therefore we propose further studies here.

-When presence of diabetes was investigated, an uncontrolled study showed an increase in HPCI whereas one controlled study showed no effect. Based on that data, we conclude that there is no evidence to support an influence of diabetes.

- When presence of heel pain was investigated, 2 studies (1 controlled) showed an increase in HPCI and 3 studies (2 controlled) showed no effect. Based on that data, we cannot rule out an effect of heel pain and future studies need to control for this entity.

Because the literature showed an effect of age, weight and a possible effect of the presence of heel pain, future studies on HPCI need to control for these factors. If these factors are not controlled for, they may become confounding factors that may hide a true effect or provoke a false effect on the behavior of the HCPI.

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