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Responsiveness of Heel Pain, Foot Function Index, Tissue Thickness, and Blood Flow in Individuals with Plantar Fasciitis

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SUMMARY

Background. The responsiveness is a psychometric property for determining the ability of clinical outcomes to detect the change of condition over time. This study investigated the responsiveness of heel pain, Foot Function Index (FFI), tissue thickness (plantar fascia and flexor digitorum brevis), blood flow, and temperature in individuals with plantar fasciitis.

Methods. The data of 30 individuals with plantar fasciitis, aged 46.67 ± 10.46 years, were collected. Heel pain, FFI, tissue thickness, blood flow, and temperature were assessed at pre-test and after the 3-week interventions. The responsiveness of each variable was analyzed.

Results. The large responsive variable in individuals with plantar fasciitis determined by the effect size (ES) was the FFI pain scale (ES, 1.53) and heel pain (ES, 1.36).

Conclusions. Regarding responsiveness, heel pain, and FFI significantly changed following the 3-week intervention program rather than tissue thickness, blood flow, and temperature in individuals with plantar fasciitis.

KEY WORDS

Heel; calcaneus; outcome assessment; physical therapy; sensitivity.

INTRODUCTION

Plantar fasciitis is characterized by heel pain and is regarded as a significant health concern, particularly among individuals whose occupations require prolonged weight-bearing activities (1-3). The initial loading of the affected heel following a period of prolonged rest can exacerbate the symptoms (1). The onset, pain characteristics (1), and other related consequences such as activity limitation (4), fascial thickness (5-7), and blood flow (7) can be investigated. Several therapeutic approaches are used to alleviate the symptoms of plantar fasciitis, including therapeutic exercises and various other interventions (2, 8).

Responsiveness is a measurement property that reflects the ability of an outcome measurement tool to detect change over time. Various statistical methods can be employed to analyze responsiveness (9). Typically, the anchor-based method is assessed by correlating the outcome measurement tool being tested with a gold standard. In contrast, the distribution-based method evaluates responsiveness through metrics such as effect size (ES), change score, and standardized response mean (SRM), which are clinically meaningful and straightforward to interpret.

The responsiveness of outcome measurement tools has been investigated in various musculoskeletal conditions, including back pain (10, 11), neck pain (12, 13), and others (14, 15). However, no studies have specifically investigated the

responsiveness of outcome measurement tools for plantar fasciitis. Outcome measures, such as morning heel pain and pain at rest (1), Foot Function Index (FFI) (4), tissue thickness (5-7, 16), and blood flow (7) need to be investigated for their responsiveness representing the measurement sensitivity. The plantar fascia contains specific hyaluronan components, along with distinct anatomical structures and innervation, which play a significant role in proprioception and nociception (17-19). The objective of the study was to assess the responsiveness of various outcome measures, including heel pain, the FFI, tissue thickness, blood flow, and temperature, in individuals with plantar fasciitis between pre-test and post-test assessments. We hypothesized that the selected outcome measurement tools would exhibit good responsiveness, as demonstrated by a significant correlation with the gold standard using the anchor-based method, and a large effect size (ES) using the distribution-based method.

METHODS

Subjects

The data was obtained from our comparative study which has been published previously (20). The data of 30 patients, 14 women and 16 men, with unilateral plantar fasciitis who gave informed consent and permitted for data analysis between May and December 2021 have been collected. The inclusion criterion is age of 18 years or over, presented with heel pain. Exclusion criteria are other musculoskeletal disorders, for example, ankle osteoarthritis, Achilles tendon rupture, history of surgery or metal implant at the lumbar spine or lower extremities, severe pain or inability of weight bearing, red flags, precautions/contra-indications, and other considerations for patient's safety and confounding factors.

Heel pain

We measured heel pain in 3 aspects, in the morning, at rest (1), and compressing with 80 N/cm^2 pressure. We used a 100-mm horizontal line of visual analog scale for those pain measurements. The pain from 80 N/cm^2 pressure was also used as the criteria for anchor-based method responsiveness (21).

Foot Function Index (FFI)

We used FFI Thai version which has 3 categories, Pain scale, Disability scale, and Activity limitation. The FFI has been proven to be reliable and valid (4).

Tissue thickness

We used the data of plantar fascia (PF) and flexor digitorum brevis (FDB) thickness which were collected with an ultrasound imaging machine (USI B-mode; CX50, Philips, NV, USA), and a transducer (broadband linear array, L12-3) (22). Our pilot study showed excellent intra-tester reliability for PF and FDB thickness.

Blood flow and temperature

We measured tissue blood flow and temperature with a Laser Doppler flowmetry machine and a fiber optic probe (Moor Instruments, Devon, UK). The probe was placed and secured on the most painful point on the plantar fascia lasted for 10 seconds, the values were averaged for the analysis (20). Our intra-tester reliability pilot study was excellent for blood flow and temperature.

Study procedure

Pre-test data were collected, including measurements of heel pain, the FFI, tissue thickness, blood flow, and temperature. Following this, all subjects participated in a three-week intervention program administered by experienced physical therapists. The program consisted of either extracorporeal shockwave therapy or high-intensity laser therapy, both targeting pain reduction and tissue healing in plantar fasciitis. Each subject received two therapy sessions per week over the course of three weeks. Post-test data were collected using the same assessments as in the pre-test. These pre-test and post-test data were then analyzed to evaluate the responsiveness of the outcome measures.

Statistical analysis

Distribution-based method

We used change scores (pre-test value minus post-test value), ES (mean change/baseline value's standard deviation), SRM (mean change/change score's standard deviation). The ES and SRM criteria for interpretation, below 0.4 (small responsiveness), 0.5 (moderate), and 0.8 (large) (23). Anchor-based methods, we used pain intensity at 80 N/cm^2 pressure as the criterion for correlating with each variable by using Pearson's correlation since the data were normally distributed following the Shapiro-Wilk normality test. The statistical significance was set at $p < 0.05$.

RESULTS

Demographic data, pre-test, post-test, and change scores in this study were shown in **table I** and **II**. The ES, SRM, and Pearson's correlation were shown in **table III**. The change scores of heel pain in the morning, at rest, and 80 N/cm^2

pressure were 31.10, 26.78, and 31.01 mm. respectively. The change score of the FFI Pain scale, Disability scale, Activity limitation, and the total score were 19.23, 20.79, 2.83, and 42.86 respectively. The change scores of the PF and FDB thickness were 0.33 and -0.11 mm. respectively. The change scores of blood flow and temperature were -4.40 and 0.44 mm. respectively.

According to the ES, FFI Pain scale was the highest (ES = 1.53), followed by FFI total score (ES = 1.42) and heel pain in the morning (ES = 1.36). According to the SRM, heel pain in the morning was the highest (SRM = 1.21). Pearson's correlation, heel pain in the morning, pain at rest and FFI Pain scale, Disability scale, Activity limitation, and the total score had significant correlations, other variables had no significant correlations.

DISCUSSION

This study analyzed the responsiveness of each outcome measure in patients with plantar fasciitis. We found that both heel pain and the FFI demonstrated significant responsiveness in terms of ES, SRM, and Pearson's correlation following the three-week interventions, regardless of whether extracorporeal shockwave therapy or high-intensity laser therapy was employed. These findings are consistent with observations made in studies related to back pain (10, 11). This finding reflected the sensitivity of these variables for measuring the change in patients with plantar fasciitis. We considered that heel pain was the most responsive to the

Table I. Demographic data of the subjects (n = 30).

Characteristics	Summary
Female/Male, n	14/16
Age, years	46.67 (10.46)
Weight, kg	65.27 (10.23)
Height, cm	164.86 (8.13)
BMI, kg/m^2	23.76 (2.55)
Duration of symptoms, months	18.40 (24.38)
Side of plantar fasciitis, n (%)	
Left side	15 (50%)
Right side	15 (50%)

Age, weight, height, and BMI are reported in mean (standard deviation).

Table II. Mean (standard deviation) of pre-test, post-test, and change scores (n = 30).

Outcomes	Pre-test scores	Post-test scores	Change scores
Heel pain			
Pain in the morning, mm	55.96 (22.73)	24.86 (23.78)	31.10 (25.69)
Pain at rest, mm	48.80 (22.26)	22.01 (22.51)	26.78 (23.81)
Pain at 80 N/cm^2 pressure, mm	51.95 (27.68)	20.93 (22.33)	31.01 (30.40)
Foot Function Index (FFI)			
Pain scale (0-90)	35.54 (12.49)	16.31 (16.45)	19.23 (19.37)
Disability scale (0-90)	37.18 (16.33)	16.39 (18.21)	20.79 (19.38)
Activity limitation (0-50)	5.54 (5.63)	2.70 (4.94)	2.83 (5.22)
Total score (0-230)	78.27 (30.09)	35.41 (37.41)	42.86 (40.24)
Tissue thickness			
Plantar fascia (PF), mm	4.02 (1.15)	3.75 (1.22)	0.33 (0.52)
Flexor digitorum brevis (FDB), mm	6.01 (1.28)	6.12 (1.12)	-0.11 (0.53)
Blood flow and temperature			
Blood flow, PU	47.43 (53.57)	51.84 (43.73)	-4.40 (45.14)
Temperature, °C	24.93 (1.87)	24.48 (1.32)	0.44 (2.14)

Table III. Absolute value of effect size (ES), standardized response mean (SRM), and Pearson's correlation of each parameter with pain at 80 N/cm^2 pressure.

Outcomes	Effect size (ES)	Standardized response mean (SRM)	Pearson r, P-value
Heel pain			
Pain in the morning, mm	1.36	1.21	0.630, < 0.001*
Pain at rest, mm	1.20	1.12	0.447, 0.013*
Foot Function Index (FFI)			
Pain scale (0-90)	1.53	0.99	0.740, < 0.001*
Disability scale (0-90)	1.27	1.07	0.810, < 0.001*
Activity limitation (0-50)	0.50	0.54	0.539, 0.002*
Total score (0-230)	1.42	1.06	0.817, < 0.001*
Tissue thickness			
Plantar fascia (PF), mm	0.28	0.63	-0.231, 0.219
Flexor digitorum brevis (FDB), mm	0.09	0.20	-0.122, 0.522
Blood flow and temperature			
Blood flow, PU			
Temperature, °C	0.08	0.09	-0.094, 0.622
Temperature, °C	0.23	0.20	-0.097, 0.611

*Denotes statistically significant difference.

interventions, not only ES, SRM, and Pearson's correlations, but the change scores of all pain measurements also exceeded 13 mm, which was greater than the proposed value by Todd *et al.* (24) determined to be clinically significant in pain as measured by VAS. The substantial change in heel pain might be due to the physiological effects of the interventions regarding pain reduction due to direct suppressive effects on nociceptors blocking the gate-control mechanism (25) and inhibition of peripheral sensitization (26, 27), respectively.

According to the FFI Pain Scale, Disability Scale, and total score, these variables exhibited high responsiveness, as indicated by ES and SRM. All domains of the FFI demonstrated significant correlations with the criterion of pain measured at 80 N/cm^2 pressure. The responsiveness of the FFI in this study aligns with findings from previous research (28) that was conducted in patients undergoing foot and ankle surgery. The previous study reported ES and SRM for Pain scales of 0.86 and 0.83, and Disability scales of 0.75 and 0.68, respectively. This responsiveness of FFI reflected that the Pain scale domain was closely related to the pain intensity measured by VAS. Also, the Disability scale and total score were other variables that reflected the recovery from plantar fasciitis affecting disability and overall impacts.

Heel pain at 80 N/cm^2 pressure was selected to be the criterion because of its standardized nociceptive input delivered to every patient since the previous study (21) reported the pressure pain threshold for healthy calcaneus of 7.8 kg/cm^2, so we set at 80 N/cm^2 for standardized pressure.

For the tissue thickness, we measured the thickness of both PF and FDB because the association of The relationship between the PF and the FDB has been postulated based on the function of the FDB, which is to distribute pressure away from the plantar fascia during the push-off phase of walking or running (29). However, the results of this study found that PF and FDB thickness were small-to-moderate responsive from the selected interventions. It is likely that changes in PF thickness were more responsive than those in FDB thickness. This difference may be attributed to the specific innervation, the presence of hyaluronan, and fibroblastic-like cells, also known as fasciacytes, in the superficial

fascia of the plantar fascia, which can influence pain perception sensitivity (17-19). Moreover, the direct effects of the interventions were focused on promoting healing and minimizing inflammatory reactions in the PF, rather than in the FDB. Recovery of the FDB is likely to occur later, as it benefits from indirect effects transmitted from the PF through changes in intrinsic foot pressure. Future studies are needed to investigate these changes biomechanically.

Blood flow and temperature were utilized as indicators of physiological changes following the three-week interventions; however, these variables exhibited low responsiveness. Blood flow showed a slight increase over time, which may reflect a gradual improvement in vascularity at the painful area of the heel. A longer follow-up period will be necessary in future studies to adequately assess physiological changes related to local blood flow in patients with plantar fasciitis. In contrast, temperature remained relatively stable over time. This may suggest that the initial impact of inflammation did not significantly elevate the local temperature at the painful heels, as the magnitude of temperature change was minimal.

There are several limitations to this study. First, our focus was on changes observed after three weeks, and a longer cohort study is warranted to monitor changes in blood flow and the thickness of the PF and FDB over an extended period. Additionally, the sample size for this study was relatively small. Furthermore, incorporating measurements of physiological agents or biomechanical variables that reflect the healing of the plantar fascia could provide a more comprehensive understanding of the recovery process.

CONCLUSIONS

In summary, our findings indicate that in individuals with plantar fasciitis, heel pain and the FFI demonstrated the greatest responsiveness following the three-week intervention program, compared to tissue thickness, blood flow, and temperature. Therefore, as clinicians and as individuals managing plantar fasciitis, it can be expected that the recovery of heel pain and associated disability will occur more rapidly and show significant improvement after a three-week intervention program.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

PS, CT, MT: conceptualization. PhoPal, PhrPak: data curation. PS, CT: formal analysis. PS, CT, MT, TB, ST: interpretation of data. PS, CT, MT, PhoPal, PhrPak, TS, TB, ST: writing – original draft, writing – review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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