**Abstract**

Background: Previous research has found that ankle joint equinus can lead to foot pathologies. Calf stretching exercises are a common treatment prescription; however, no dynamic quantitative data on its effectiveness is available.

Objective: To investigate the effect of calf muscle stretching on ankle joint dorsiflexion and subsequent changes within dynamic forefoot peak plantar pressures (PPP), force and temporal parameters.

Method: Thirteen runners with ankle joint equinus were required to perform calf muscle stretching twice a day (morning and evening) on a Flexeramp. Measurements were collected on day 1, week 4 and week 8. A repeated measures ANOVA with Bonferroni-adjusted post hoc comparisons was used to assess differences across the three data collection sessions.

Results: Findings indicated that the calf stretching program increased ankle joint dorsiflexion significantly (from 5° to 16°, p ≤ 0.05). The adaptive kinetics brought about by the increased ankle joint range of motion included significantly increased forefoot PPP and maximum force during stance phase but decreased time between heel contact and heel lift and total stance phase time.

Conclusion: The calf stretching programme used in this study was found to increase ankle joint dorsiflexion and hence can be used for first line conservative management of ankle equinus.

Keywords: foot; dorsiflexion; ankle joint equinus; peak plantar pressure; calf stretching; Achilles Tendon lengthening

**1. INTRODUCTION**

Previous investigations have documented that restricted ankle joint range of motion (ROM) which is also known as an ankle joint equinus, can lead to many pathologies as there is a loss of gradual absorption of energy which is controlled by dorsiflexion through a flexible gastrocnemius and soleus complex 1. With altered muscle firing patterns, extensor digitorum longus and extensor hallucis longus muscles can become overactive in an attempt to assist dorsiflexion by the relatively weak anterior tibial muscles 2. As these muscles insert into the distal phalanx of the 1st digit, hyperextension can occur over time as well as resultant lesser toe deformities 2. Hammertoes and shortening of the muscles can also lead to distal migration of the metatarsal fat pad, therefore, reducing the forefoot cushioning. Various investigations have demonstrated that shifting the plantar weight from the hindfoot to the forefoot places excessive pressure on the plantar aspect of the forefoot 2,3,4,5,6. Furthermore, with an ankle joint equinus, the forefoot will contact the ground prematurely creating increased plantar pressure 7, which may remain relatively high for most of the stance phase, rather than mainly at the latter portions of stance during push-off 8,9. Orendurff et al. 3 and Springett 10 propose that this prolonged period with limited arterial perfusion to the forefoot plantar tissue could increase the risk of ulceration or impede the healing of a pre-existing ulceration.

To reduce the pathological pressures and forces and improve dynamic gait, calf stretching exercises are commonly prescribed and are probably the most common clinical approach to treating an ankle joint equinus 11,12. Some studies have documented the effects of stretching the calf muscle complex (gastrocnemius and soleus) monitoring the resultant changes within the ankle joint ROM 13,14,15,16,17,18,19,20. As indicated in Table 1, it could be concluded from these studies that the longer you stretch the more likely it is to have a positive effect. None of these studies, however, used dynamic quantitative measuring tools e.g. in-shoe pressure analysis equipment or an objective bipedal pre-calibrated angled stretching device and therefore it could be suggested that clinical relevance cannot be assumed. Some studies have investigated the effects of a tendon Achilles surgical lengthening procedure (TAL) in an attempt to specifically reduce forefoot peak plantar pressure (PPP) 4,5,6,21,22,23. While these investigations as shown in Table 2 have demonstrated a reduction in the forefoot PPP using pressure platform systems, there is a paucity of information on dynamic pressure and temporal aspects using in-shoe pressure assessment.

Attempting to address this gap, the main objective of this study was to establish if there was any evidence for calf stretching as a conservative and safe treatment to increase ankle joint dorsiflexion. Whilst hypothesising that; calf stretching will increase the ankle joint dorsiflexion ROM, a reduction in forefoot PPP and force but an increase in the heel contact time and overall stance phase time was expected.

**2. METHODS**

*2.1. Participants*

Ethical approval was granted by the university ethics committee and all participants gave full informed consent. Thirteen runners (4 male and 9 female) with an average age of 34.43 years (SD 7.45), height of 170.65cm (SD 0.09), weight of 67.24kg (SD 0.09) and shoe size of 7.23 UK (SD 1.57) participated in the study. The participants included in the investigation were all injury free (for at least 2 years), had no known musculoskeletal pathologies, had ≤ 6° of ankle joint dorsiflexion with the knee extended and no bony restriction, and had a foot posture index 24 of ≤ +8 or ≥ -8 . The foot posture index is a validated numerical grading system for static foot posture and this therefore allowed exclusion of extreme foot types e.g. pes planus or pes cavus.

*2.2. Equipment:*

A double armed full circle protractor goniometermade of transparent plastic was used to measure ankle joint ROM with the standard operating procedures as explained by Valmassy 12. To measure ankle joint ROM the subtalar joint was placed in a neutral position, with the transcondylar axis of the knee in the frontal plane and the knee fully extended. The goniometer was placed at the level of the ankle joint with one arm along the lateral leg bisection and the other along the lateral margin of the foot. The experimenter then applied a loading force to the forefoot to allow the ankle joint to dorsiflex to its end ROM and this measurement of ankle dorsiflexion was recorded from the goniometer. The ankle joint dorsiflexion was measured three times and averaged during each data collection session. A Flexeramp™ (Scotland, UK), a simple adjustable inclined platform, was used as a bipedal stretching device but was also used as an ankle joint dorsiflexion measurement tool. Orendurff et al.3 suggested diagnosing an equinus may be improved further if the applied dorsiflexion torque is normalized to body weight and the use of the Flexeramp achieves this, as the participant is standing during measurement, as well as eliminating the subjectiveness of applied magnitude. As indicated in previous literature approximately 12° of ankle joint dorsiflexion is required for normal ambulation 25. The Flexeramp stretches both legs simultaneously (a bipedal stretch) and has an inclined adjustable surface of 5°, 10°, 14°, 17° and 20°. Participants were given verbal, written and pictorial instructions on using the Flexeramp; their feet were positioned facing up the ramp to achieve ankle joint dorsiflexion, and toes turned in slightly to allow an equal dorsiflexion stretch across the calf muscle complex. They were requested to stand upright without an arch in the lower back/and or flexing at the hips. If the participant could not achieve an upright body position the ramp angle was set too high and they were instructed to reduce the angle.

An in-shoe pressure measurement device (F-Scan, Tekscan Inc., USA) was used to measure dynamic plantar pressure, force and time variables. In the context of this paper, the term force refers to the vertical ground reaction force as measured by the pressure analysis equipment. The system was calibrated and the data collected as per the manufacturer’s guidelines. Sites which have been recognised as adequately representing the forefoot were identified and masked; the 1st, 2nd and 5th metatarsal phalangeal joint (MTPJ) 26 as well as the hindfoot, midfoot and forefoot. The masking of the foot regions was manually performed by one researcher for all trials through visual inspection of the pressure profile. Experienced practitioners have been shown to demonstrate good intra-observer reliability when masking foot regions 27. The mask size for each area was adapted as necessary to allow for anatomical variation between participants. All participants were supplied with standardised socks (Marks and Spencer, UK, plain crew socks - 75% cotton, 24% polyamide and 1% elastane lycra) and footwear (Primark, UK, fastened, rubber sole causal trainer) with a heel height of 1.5cm and a forefoot height of 0.5cm in appropriate sizes. These socks and shoes were only worn by the participants for the data collection sessions. Using the same socks and shoes with each participant during each data collection was vital in order to reduce the variable effects that can be created through different sock and shoe properties 28.

*2.3. Procedure*

Initial baseline measurements using the goniometer, Flexeramp and F-Scan were collected with one investigator recording all measurements at each data collection session. Each participant was allocated their own new pair of F-Scan in-shoe measuring insoles and a treadmill was used to standardise walking terrain and control walking speed. While speed effects walking plantar pressures 29,30,31, studies indicate that in-shoe pressure measurement during treadmill walking is reliable 32. Each participant selected their own comfortable walking speed, which was recorded and repeated for each data collection session. A Flexeramp with written instruction sheets and a diary was then issued to all participants and they were asked to stand on a Flexeramp for 4 continuous minutes first thing in the morning and last thing at night. The participant recorded in the diary the angle of the ramp, the length of time they stretched for and also made comments regarding comfort on their diary sheets. Participants returned after 4 weeks for data collection with the purpose of this session not only to assess any changes that may have occurred in 4 weeks verses previous studies but also to improve participant compliance and motivation. As previous studies 17,19,20 measured no statistically significant increase in ankle joint dorsiflexion after a maximum of 6 weeks of stretching this study was carried out over an 8 week period. The participants followed the same stretching programme for another 4 weeks and returned for the final data collection (Week 8).

*2.4. Data Analysis*

Variables analysed were peak pressures under the 1st,2nd and 5th MTPJ, maximum force during stance, total stance phase duration, cadence and time of heel contact to heel unloading during walking and ankle joint dorsiflexion and Flexeramp angles. Force measurements were normalized to body weight. The middle three steps from the recorded F-Scan trials were used to extract the pressure and temporal data. Using the mean result of three steps has previously been shown to produce excellent reliability 33. A repeated measures ANOVA (p ≤ 0.05) with Bonferroni-adjusted post hoc comparisons was used to assess differences across the three data collection sessions.

**3. RESULTS**

Mean values for goniometer, Flexeramp and F-Scan in shoe measurements are presented in Table 3. Following 8 weeks of stretching ankle joint dorsiflexion increased significantly (p ≤ 0.05) with goniometer measurements indicating an average increase of 11° for the left foot and 10° for the right foot. From baseline to week 8 there was a significant increase in PPP at the 1st and 2nd MTPJ for both feet and for the 5th MTPJ on the right foot. Also a significant increase for maximum force on the right foot during stance phase was evident. A significant decrease in stance time for both feet was evident at week 4 and this was maintained at week 8. Heel contact time also significantly decreased for both feet from baseline to week 8.

**4. DISCUSSION**

Based on the findings of previous research 3,5,6,34,35, dynamic forefoot PPP was expected to decrease after stretching the calf muscle complex. However, the dynamic forefoot PPP increased on completion of the stretching programme along with an increase in the ankle joint dorsiflexion. These results would seem to contradict previous beliefs and research 2,34,35 but the overall results indicate some interesting and alternative theories given the resultant changes.

After the stretching programme the static ankle joint dorsiflexion increased by over 200% between baseline and week 8 (on average the ankle joint dorsiflexion increased from 5° to 16°, p ≤ 0.05), and dynamically there was an increase in PPP at the 1st and 2nd MTPJ for both feet and for the 5th MTPJ on the right foot. All participants had therefore gained “normal” ankle joint dorsiflexion but increased PPP. These results may therefore question whether an ankle joint equinus is the only possible cause of increased forefoot PPP, particularly as there appears to be a growing trend to lengthen the Achilles tendon surgically in an ulcerated, diabetic equinus foot 4,5,6. Aronow et al. 2 and other texts 11,12 claim that a common and well-recognized compensation for an ankle joint equinus, is an early heel lift. As all participants no longer had an ankle joint equinus the results of this study, therefore, expected to show an increase in heel contact time but instead the results displayed a reduction in contact time. While, there was undeniably an increase in PPP recorded numerically in the forefoot, graphical representation indicated that the location and area had changed as well as a decrease in contact time. It is also well recognized that in compensation for an ankle joint equinus the foot pronates and dorsiflexion occurs around the midtarsal joint long axis thus creating a hypermobile foot 4,11,12. If after increasing the ankle joint dorsiflexion, the midtarsal joint no longer needs to unlock for such a long period of time, logically the foot should then be allowed to resume “normal” mechanics with improved elastic energy. “Normally” the foot supinates and becomes rigid during propulsion and toe-off. The increase in forefoot pressures and the change in location may well be a by-product of improved gait allowing the improvement/reintroduction of the Hicks windlass mechanism 36 during toe-off, rather than a by-product of a pathological gait. This improvement may also allow for a greater or more effective contraction of the intrinsic muscles of the foot which aid the windlass effect thus also contributing to the resultant change in forefoot pressures. It could be speculated that as the foot can now function more like a rigid lever this in turn would increase the efficiency of transmitting energy during toe-off. If the foot is functioning with increased rigidity at toe-off there should also be an increase within the ground reaction force which will directly produce acceleration changing the velocity and possibly creating kinetic adaptations e.g. increasing the PPP. This theory is also supported by the fact that not only were there changes present within the temporal heel component but also the overall stance phase time. Interestingly participants verbally reported improved running times as their flexibility increased. However, further functional measures were not performed on the runners. With “normal” ankle joint dorsiflexion the participants forefoot PPP increased but the stance phase time decreased. This may be indicating that the duration and location of PPP plays a role in creating forefoot pathologies. As this study used healthy participants it is difficult to compare the effects to the diabetic foot and it would therefore be interesting to repeat this study with participants who suffer with diabetes mellitus. The decreased heel contact and stance phase time may also be indicating a change in cadence however no significant difference was evident in cadence over the 8 weeks.

The results of this study clearly indicated that a relationship exists between the degree of the available ankle joint dorsiflexion and dynamic forefoot PPP but further studies are needed to determine the exact cause-effect relationship. Although this study did not produce statistically significant results for the loading of the 5th MTPJ on the left foot, this could be attributed to small errors associated with defining measurement areas within the plantar pressure assessment software during the masking process or footwear fitting. This 8 week stretching programme for the calf muscle complex of runners with an ankle joint equinus increased the maximum dorsiflexion angle by over 200%, increased the maximum force during stance phase for the right foot, decreased the time of stance phase, decreased the time in which the heel was in contact with the ground and increased the forefoot peak plantar pressures. Further in-depth investigations into the change in peak pressure and force during heel strike as well as the heel contact time are warranted.

Although, the findings from this study cannot fully explain the mechanism of how improved ankle joint dorsiflexion increased dynamic forefoot PPP it may be possible that the increased dorsiflexion has allowed for more “normal” foot function. The increased pressures which are now applied for a shorter period of time over a greater and more even distribution within the foot may be less harmful to the foot. Although these results appear to contradict initial beliefs, they indicate that a relationship between the ankle joint dorsiflexion and PPP, force and temporal parameters, do exist but warrants further investigations. Further studies are required to substantiate these results. The results from this study support the specific calf muscle stretching regime which used a Flexeramp as an effective way to increase the ankle joint dorsiflexion. These results also strongly indicate that this specific non-invasive stretching regime could be considered before resorting to more invasive options.

**5. STUDY LIMITATIONS**

The method of masking the in-shoe pressure measurement could have created variations within results. Although, templates were created they had to be adjusted for each participant to allow for variations in foot morphology. Unless the computer programmes can identify these areas, future research may be improved by splitting the whole of the forefoot into 3: one area covering the 1st MTPJ, another covering the 2nd, 3rd and 4th MTPJ and a final area covering the 5th. This divide allows analysis of the independent movement of the 1st and 5th. Furthermore, the number of participants used may have limited or influenced the results. Increasing the sample size as well as introducing a control group would provide more information.

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Table 1. Calf muscle complex stretching studies.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Author** | **Participants**  | **Control group** | **Intervention** | **Intervention****Dosage** | **Measurement Equipment** | **Results** |
| Gadjosik et al. (2007) | 12 females aged 18-31.Inclusion: 1)Minimally active 2) Did not participate in any stretching or strengthening program. 3) Free of neurologic or orthopaedic disorders | Yes 4 subjects | CALF STRETCH1) Leaning into the wall bending the front leg and stretching the back leg. | 6 week stretching programme, 5 days per week, holding for 15s repeating 10x, Max stretch time = 75 min over 6 wks. | Kin-Com dynamometer | Statistical significant difference between the stretching and the control group of 7° ± 4° dorsi flexion (p=0.017).  |
| Gadjosik et al. (2005) | 19 females aged 65-89Inclusion: 1) ≤ 10 ° ankle joint dorsiflexion2) No history of orthopedic or neurological conditions | Yes  | CALF STRETCH1) Standing static calf stretch leaning into the wall. | 8 week stretching programme, carried out 3 times per week. Stretch held for 15s with 10x on both legs. Max stretch time = 60 min over 8 wk’s. | Kin-Com Isokinetic dynamometer. A timed agility course, a timed fast 10m walk, and a standing forward functional reach test. | Statistical significant difference between the stretching and the control of 5.1° dorsi flexion (p=<0.001) |
| Yeh et al (2005) | 30 (20 male & 10 female, aged 42-72). Inclusion: 1) Spasticity in lower limb, 2) no joint deformity, 3) no pain in lower limb 4) no history of neurologic disorder 5) must be hemiplegic from cerebrovascular accident. | No | CALF STRECH1) Non-weight bearing using a motor driven sinusoidal stretching device. | 2 week stretching programme. A prolonged muscle stretch for 30 minutes once a wk. Max stretch = 60 min over 2 wk’s. | Motor driven sinusoidal stretching device | Statistical significant change occurred with an increase of 8°± 4° dorsi flexion (p= <0.01) |
| Guissard and Duchateau (2004) | 12 (8 males & 4 female aged 21-35).Inclusion: 1) Volunteers well experienced with experimental procedures, 2) no signs of neurological disorders. | Yes left leg was used as the control | CALF STRETCH1) Standing static calf stretch leaning into the wall.2) Standing static calf stretch with foot on the wall.3) Long sitting calf stretch.4) Standing calf stretch on a step. | 6 week stretching programme, carried out 5x per wk. The 4 stretches were alternated and held for 30s, 5 times with a 30s rest between each. Max stretch time = 60min over 6 wks | Strain gauge tranducer. | 30.8% (p< 0.01) increase in dorsi flexion. |
| Youdas et al. (2003) | 101 (38 males & 63 females, aged 30-50).Inclusion: 1) No block to the talorcrural joint that would limit ankle joint plantar/dorsi flexion, no limitation in the subtalar joint mobility. 2) No previous history of calf muscle trauma that required surgery. 3) No visual aid of gait impairment due to lower extremity dysfunction. 4) All subjects agreed not to start new activities or increase their regular activities. | Yes the left leg was used as the control | CALF STRETCH1) Standing static calf stretch leaning into the wall. | 6 week programme, stretching right calf muscle comlpex once a day, 5 days per week.Group 1: control group.Group 2: carried out 1 stretch for 30s. Group 3: carried out 1 stretch for 1 min.Group 4: carried out 1 stretch for 2 min Max stretch = 60min over 6 wks | Universal goniometer with the same physiotherapist taking all the measurements | No statistical significant difference (p>0.05).(G1 p=0.23, G2 p=1.0, G3 p=0.94, G4 p=0.72). |
| Petty et al. (2000) | 7 aged 76-85.Inclusion: 1) Older than 65 2) ankle joint equinus of <0° 3) ability to stand without external support.  | No | CALF STRECH1) Leaning into the wall stretching the straight leg. | 4 week programme. Stretching both feet. Stretch was maintained for 30 seconds repeated 4x with 15 seconds of rest between each. Repeated 2x a day. Max stretch time = I hr 86min over the study. | Goniometer | Prior to stretching ankle joint ROM = -5.9° ± 2.5° and post study mean change of 6.4° ± 2.2° occurred (p<0.05). |
| Muir et al. (1999) | 20 males agde 21-40. Inclusion: 1) 10° of ankle dorsi and plantar flexion. 2) Functionally independent. 3)Report no history of orthopedic, rheumatologic or neurological disorders involving the ankle, back or lower extremities to be included. Excluded if they had participated in sport in the previous 4 hours. | Yes  | CALF STRETCH1) Leaning into the wall (stretching the straight leg). The control leg bent and the intervention leg was straight. | The stretch was repeated 4x, holding for 30s with 10s rest period. Results before and after one set of stretching only were measured.Max stretch time = 2 min on one day. | Isokinetic Dynameter | No statistical significant difference (p>0.05). |
| Zito et al. (1997) | 19 aged 21-40.Inclusion: 1) No musculoskeletal pathologies, 2) Bilateral ankle joint equines, 3) No previous ankle or knee joint injuries requiring medical intervention. | Yes.One leg was the control and one leg was stretched. | CALF STRETCHStanding on a platform the relevant heel was dropped off the edge with their hands on a parallel bar  | Stretched twice only, holding for 15s with four 5s dorsi flexion contraction between. Results were taken immediately after the stretch then after 90s, then after 10min and finally after 24 hours.Max stretch time = 50s on one day | Photography and a protractor. | No statistical significant difference (p> 0.05). |

Table 2. A summary of research carried out into the effects of Tendo-Achilles Lengthening (TAL) procedures.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Author** | **Participants** | **Intervention** | **AKJ Measuring****Equipment** | **Pressure Equipment** | **Outcome Measure** | **Walking Velocity Controlled** | **Results** | **Results 7-8months post treatment.** |
| Salsich et al. (2005) | 29 diabetic subjects aged 44-64. Inclusion: 1) Loss of sensation. 2) ankle joint equinus < 5°. 3) Recurrent non-healing plantar ulcer. | 15 TAL & 14 total-contact casting. Post treatment both groups followed a home stretching program (resisted ankle plantar flexion, dorsi flexion, inversion and eversion using Thera-band 3 set, 10x once a day 3-5 x per week.) | Kin-com isokinetic dynamometer | Not used | 1) Maximum dorsi flexion angle. 2) Concentric plantar flexion peak torque. 3) Dorsi flexion peak torque. 4) Plantar flexion passive torque. | N/A | 1) Maximum dorsi flexion angle increased 11° after TAL (p≤0.05) No diff in the total-contact casting dorsi flexion angle. 2) Concentric plantar flexion peak torque decreased by 31% after TAL (p≤0.05). No change in total-contact casting. 3) Dorsi flexion peak torque no difference in either group. 4) Plantar flexion passive torque 64% reduction post TAL (p≤0.05). No change in total-contact casting. | @ 8 months 1) Remained. 2) Returned to baseline. 3) NA. 4) Returned to baseline. |
| Willrich et al. (2005) | 3 diabetic case studies. Aged: 1) 63, 2) 68 & 3)74. | TAL | Not provided | Not used | Ulcer healing rate | N/A | Subject 1 ankle joint dorsi flexion ROM pre-opp. -1°, post-opp. 10°, ulcer healed within 9 weeks. Subject 2 ankle joint dorsi flexion ROM pre-opp. -8° & post opp. 6°, healed within 7 weeks. Subject 3 ankle joint dorsi flexion ROM pre-opp. -2° post opp. 8° healed 11 months after surgery. | Not followed up. |
| Maluf et al. (2004) | 28 diabetic subjects aged 45-63. Inclusion: 1) Neuropathic foot. 2) Plantar ulcer Wagner grade 2. 3) <5° DF at the talocrural joint. | 14 TAL & 14 total-contact casting. Post treatment both groups followed a home stretching program (resisted ankle plantar flexion, dorsi flexion, inversion and eversion using Thera-band 3 set, 10x once a day 3-5 x per week.) | Video analysis using Kintrack 5.7 software (CA, USA) | Platform Emed (Novel) pressure equipment. | Barefoot data 1) Forefoot mean peak pressure (PP). 2) Forefoot Mean pressure time integral (PTI). 3) Hindfoot mean (PP) 4) Hindfoot mean PTI | No | TAL 1) Decreased from 89.24 N/cm² to 64.72 N/cm² (p≤0.001). 2) Decreased from 22.18 N/cm² to 12.76 N/cm² (p≤0.001) 3) Increased significantly (p=0.007). 4) Increased significantly.Total-contact casting no significant difference (p=0.265). | @ 8 months TAL: 1) Increased to 88.78N/cm². 2) Increased to 16.81 N/cm² but lower than pre. 3) Remained similar. 4) Remained similar. |
| Mueller et al. (2003) | 64 diabetic subjects aged 46-66. Inclusion: 1) Neuropathic foot. 2) Palpable ankle pulse. 3) Plantar forefoot ulcer Wagner grade 2. 4) <5° dorsi flexion at the talocrural joint. | 31 TAL & 33 total-contact casting. Post treatment both groups followed a home stretching program (resisted ankle plantar flexion, dorsi flexion inversion and eversion using Thera-band 3 set, 10x once a day 3-5 x per week.) | Goniometer for ankle joint ROM & a isokinetic dynamometer (Kin-com, Tennessee) for concentric peak torque of plantar flexion muscles | Platform Emed (Novel) pressure equipment. | Barefoot data. 1) Forefoot peak pressures (PP).2) Hindfoot PP. 3) Flexor peak torque | No | TAL increased dorsi flexion from -4.1° to 11.1° (p≤0.001). 1) Reduced from 89.24 N/cm² to 64.72 N/cm² (p≤0.0002). 2) Increased from 52.17 N/cm² to 70.06 N/cm² (p≤0.018). 3) Decreased from 35.4 Nm to 23.9 Nm (p≤0.001). | @ 7months: Increased dorsi flexion remained 10.8° (p≤0.001) 1) Increased to 88.78N/cm². 2) Remained similar 70.62N/cm². 3) Increased 34.4Nm (p=0.001). |
| Armstrong et al. (1999) | 10 diabetic subjects aged 48-58. Inclusion: 1) Neuropathic foot. 2) Plantar ulcer | 10 TAL | Tractogragh | Platform Emed (Novel) pressure equipment | Barefoot data 1) ankle joint dorsi flexion. 2) Forefoot mean peak pressure | No | 1) TAL increased dorsi flexion from 0° to 9°. 2) Decreased from 86 N/cm² to 63 N/cm² (p<0.001). | N/A |
| Lin et al. (1996) | 36 diabetic subjects aged 40-70. TAL Inclusion: 1) Post 9 week’s in total-contact casting plantar ulcer still present. 2) Ulcer Wagner grade 1. 3) ankle joint equinus | 15 TAL & 21 total-contact casting | Goniometer | N/A | Ulcer healing rate | N/A | TAL ankle joint dorsi flexion increased from 0° to 9°. The ulcers healed in an average 39.3 days. Total-contact casting ulcers healed in an average 43.5 days. No statistical analysis. | TAL @17.3 months no ulcer reoccurrence. Total-contact casting @ 6 wk’s 4 subjects had ulcer reoccurrence. Dorsi flexion angle was not recorded. |

Table 3. Mean (standard deviation) for variables recorded at each data collection session.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **Baseline** | **Week 4** | **Week 8** |  |  |  |  |
| Flexeramp angle (°) | 5 (0) | 13 (3) | 14 (3)a |  |  |  |  |
| Cadence (steps per minute) | 106.46 (5.98) | 108.74 (6.25) | 108.56 (5.05) |  |  |  |  |
|  | **Left foot** |  | **Right foot** |
|  | **Baseline** | **Week 4** | **Week 8** |  | **Baseline** | **Week 4** | **Week 8** |
| Ankle joint dorsiflexion (°) | 5 (1) | 10 (3) | 16 (3)b |  | 5 (1) | 10 (3) | 15 (3)b |
| Foot Posture Index | 3 (2) | 3 (3) | 4 (1) |  | 4 (2) | 3 (2) | 3 (2) |
| Peak pressure 1st metatarsal phalangeal joint (kPa) | 281.64 (84.21) | 351.79 (84.28) | 395.26 (137.57)c |  | 397.97 (146.19) | 419.03 (130.23) | 508.77 (181.87)c |
| Peak pressure 2nd metatarsal phalangeal joint (kPa) | 464.54 (172.36) | 585.92 (204.13) | 736.74 (251.94)b |  | 401.10 (161.84) | 477.49 (160.06) | 621.97 (205.77)b |
| Peak pressure 5th metatarsal phalangeal joint (kPa) | 216.13 (64.34) | 184.67 (74.32) | 211.46 (85.75) |  | 134.23 (62.84) | 155.92 (63.15) | 195.00 (69.74)c |
| Maximum force (N/BW) | 1.21 (0.09) | 1.30 (0.12) | 1.34 (0.13) |  | 1.18 (0.10) | 1.22 (0.07) | 1.39 (0.16)d |
| Stance time (s) | 0.66 (0.04) | 0.63 (0.04) | 0.62 (0.04)a |  | 0.65 (0.04) | 0.62 (0.04) | 0.61 (0.03)a |
| Time heel contact to unloading (s) | 0.17 (0.02) | 0.16 (0.03) | 0.15 (0.02)c |  | 0.17 (0.02) | 0.16 (0.02) | 0.15 (0.03)c |

a Indicates significant difference between baseline and both week 4 and 8 (p ≤ 0.05); b Indicates significant difference between all data collection sessions (p ≤ 0.05); c Indicates significant difference between baseline and week 8 (p ≤ 0.05); d Indicates significant difference between week 8 and both baseline and week 4 (p ≤ 0.05).