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RESEARCH ARTICLE

METATARSUS ADDUCTUS IN TODDLER: A COMPARISON OF TWO DIFFERENT TREATMENT APPROACHES

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ABSTRACT

Metatarsus adductus is a common pediatric disorder related to intrauterine molding. Severe mid flexible metatarsus adductus may need a serial casting or special bracing to avoid the need for surgical intervention. Therefore, the aim of this study was to compare between the effects of the serial plaster casting and combined treatment program consisting of both rigid strap taping and selected exercise program in correcting metatarsus adductus of toddler children. Thirty children with bilateral severe mid rigid metatarsus adductus of both sexes whose age ranged from 2 to 3 years were included in the study. They were assigned randomly into two groups of equal number. The casting group was treated with serial plaster casting and the strapping group was treated with a combined treatment program consisting of both a rigid strap taping and selected exercise program. The exercise program lasted for 1 hour/ 5 times/ week. The functional activity by using Peabody Developmental Motor Scale-version 2 as well as weight-bearing anteroposterior and lateral view radiographs were evaluated before and after successive eight weeks of treatment. Significant differences were recorded when comparing the pre and post treatment mean values of the radiographic measurements in both groups ($p < 0.05$), without worsening of the heel valgus. Also, significant differences were recorded in the functional activity of strapping group ($p < 0.05$) while no significant differences were recorded in casting group ($p > 0.05$). There were no significant differences in both groups when comparing their post treatment mean values of radiographic measurements ($p > 0.05$). Meanwhile, significant differences were recorded between both groups in favor of the strapping group when comparing their post treatment mean values of functional activity ($p < 0.05$). Based on the obtained results, a combined treatment program consisting of both a rigid strap taping and selected exercise program is an excellent decision for correcting metatarsus adductus in toddler children with severe mid rigid metatarsus adductus.

INTRODUCTION

Metatarsus adductus (MTA) involves adduction of the forefoot in relation to the hind foot (Kliegman *et al.,* 2007). It is the most common congenital foot deformity with an incidence of 1 in 1000 and the risk of the second affected child is nearly 1 in 20. Bilateral deformity will be present in 50% of patients. It is typically seen in the first year, although capable of presenting at any age. Torticollis and hip dysplasia are associated in 10-15% of the patients (Giovanni *et al.,* 2007). So, a careful examination of the hip should be done for those patients (Staheli, 2006). It is believed to be a direct result of the positioning of the baby inside the womb. The differential diagnosis for MTA is clubfoot. Clubfoot is a more complex foot disorder that includes three separate deformities, of which MTA is one (Scherl, 2004). Bleck (Bleck, 1983) had classified this deformity into mild, moderate and severe based on the position of the heel bisector line. An imaginary line drawn to bisect the heel normally goes through the 2nd toe or the second web space. In MTA, this line appears more lateral than the 2nd toe. In mild deformities, the midline of the foot runs through the third toe. In moderate MTA deformities, it falls between the third and fourth toes. In severe deformities, the line is lateral to the third web space. He also further distinguished between those that are fully flexible (if one can passively overcorrect the deformity), partially flexible (if one can passively correct the foot to the neutral position only), and rigid (where no passive correction is obtainable). In the less flexible forms, a skin crease is often present.

Most cases of MTA can be treated with observation and simple passive stretching (Katz *et al.,* 1999; Bohne,1987), but approximately 11–14 % are persistent and require treatment (Bleck, 1983). The treatment of MTA is based on the rigidity of the deformity; most children respond to non-operative treatment. Deformities that are flexible and overcorrect into abduction with passive manipulation may be observed. Those feet that correct just to a neutral position may benefit from stretching exercises and retention in a slightly overcorrected position by a splint or reverse-last shoes. These are worn full

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time (22 hours/day), and the condition is re-evaluated in 4–6 weeks. If improvement occurs, treatment can be continued. If there is no improvement, serial plaster casts should be considered. Feet that cannot be corrected to a neutral position may benefit from serial casting (Kliegman *et al.,* 2007).

In severe cases, compensation at the mediotarsal joint could lead to the development of hammer toe, bunions or other disorders (Yu and Wallace,1992)**.** Therefore, severe MTA can be referred for serial casting and bracing (Churgay, 1993). Casting is most effective if started before child reaches one year of age, but casting can be effective in children up to age of 4-5 years. Persistent or rigid forefoot adductus can be readily corrected with cast (Wheeless, 2012). There are different types of taping materials and techniques: rigid strapping tape can be used to stabilize or support a ligament injury or facilitate normal movement. Elastic strapping tape can be used when less support or rigidity is required for example, supporting a muscle strain. Kinesiology tape is a type of elastic tape that assists muscular function during movement (Iona Physiotherapy ?).

A systematic literature review was conducted to answer the following question: For a child who presents with MTA, what is the most evidence-based conservative treatment option?. Thirteen articles were reviewed. Conservative treatment options reported on included the following: no treatment, stretching, splinting, serial casting, sitting and sleeping positions and footwear/orthotics. There was strong evidence supporting no treatment in the case of flexible MTA. Some limited evidence was found for the treatment of semi-rigid MTA (Williams *et al.,* 2013). Therefore, the aim of this study was to compare the effects of the serial plaster casting to that of the combined treatment program consisting of both a rigid strap taping and selected exercise program in correcting MTA of toddler children.

Subjects, randomization and methods

Subjects

Thirty children with bilateral MTA of both sexes (15 boys and 15 girls) were included in this study. Their ages ranged from 2 to 3 years. They were recruited via Al-jahra and Al-Razi Hospitals, Ministry of Health, Kuwait. They had severe mid rigid MTA deformity that could not be corrected passively to the neutral position. They were able to walk independently with in-toeing and repetitive falling. Children who had one or more of the following criteria were excluded from the study: any surgical intervention to correct lower-extremity orthopedic abnormalities, hip dysplasia, club feet, internal tibial torsion, increased femoral anteversion, MTA varsus, arthrogryposis or other chromosomal defects, previous history of fracture, severe muscle contracture or the presence of subluxation or dislocation and any medical conditions that would severely limit a child's ability to participate in the study such as hearing or vision loss. The children were randomly assigned into two study groups of equal number: casting (7 boys and 8 girls) and taping (8 boys and 7 girls). All procedures involved for evaluation and treatment, purpose of the study, potential risks and benefits were explained to all children and their parents. A signed consent form was taken from each parent before participation in the study. This work was carried out in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Randomization

Thirty-four children were assessed for eligibility. Four children were excluded as they did not meet the inclusion criteria. The functional assessment through Peabody Developmental Motor Scale-version 2 (PDMS-2) and radiological assessment of the feet were evaluated. Following the baseline evaluation of each child, randomization process was performed. The children were randomly assigned by closed envelopes into one of two groups: casting group (n =15; serial casting); and strapping group (n= 15; rigid strap taping and a selected exercise program).The principle investigator prepared 30 closed envelopes. Each envelope containing a card labeled with either casting group or strapping group. The treatment allocation was disclosed to the child and the parent immediately after the baseline evaluation. Each child or the parent was asked to draw a closed envelope. The randomization was conducted by a physiotherapist who was not involved in delivering the interventions. All children received the therapy in the same environment, the same fashion and from the principal investigator. The design of the study is demonstrated as a flow chart in Figure 1.

MATERIALS AND METHODS

For evaluation

The functional assessment through Peabody Developmental Motor Scale-version 2 (PDMS-2) and radiological assessment of the feet were evaluated by the principal investigator pre treatment and post treatment (after successive eight weeks of treatment).

Radiological assessment

Radiographs were taken during weight bearing or in a simulated weight bearing (sitting on a stool with the knees flexed to 90°). Measurements on the lateral view included the talocalcaneal (Kite) angle. Measurements on the anteroposterior view included the talocalcaneal angle, the calcaneo-fifth metatarsal angle, and the talo-first metatarsal angle (Van der Wilde *et al.,* 1988) as presented in figure 2 (Herzenberg *et al.,* 2013). A single radiologist, who was blinded to the patient name and protocol, measured the radiographs. Kite's angle is a starting point in measuring MTA to exclude the hind foot deformity (Ganley *et al.,* 1992). It refers to the angle between lines drawn longitudinally thru the central axis of talus and parallel to the lower border of the body of the calcaneus. It is normally 30-50 degrees. On lateral view, this angle should be between 35 - 40 degrees (Wheeless, 2012). If the upper limit on the lateral radiograph is exceeded, the hind part of the foot is considered to be in valgus angulation (Berg, 1986). Once the hindfoot deformity is ruled out, the talo-first metatarsal angle is a reasonable method of displaying any adductus deformity.

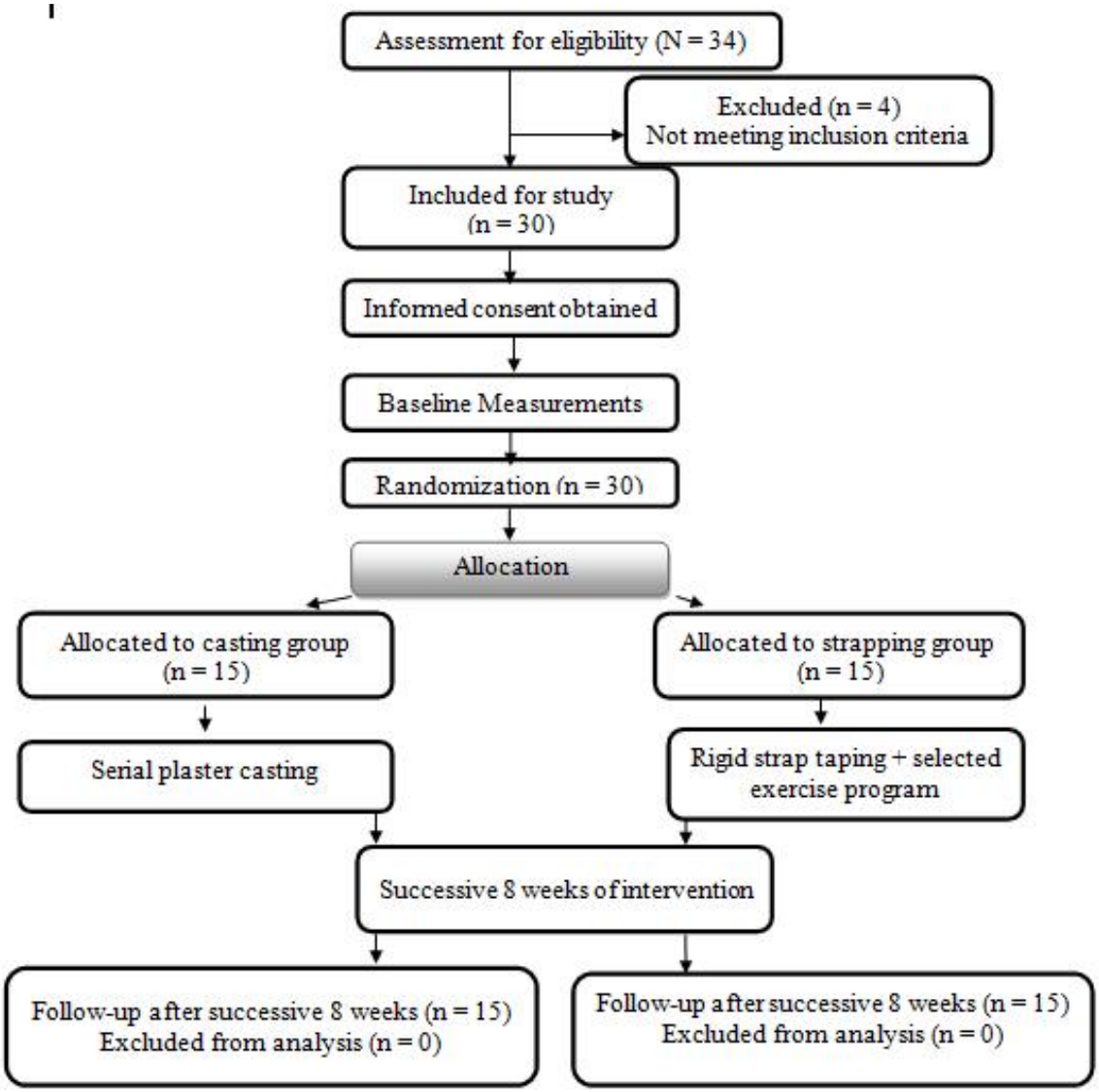

Figure 1. Flow chart of the study design

It refers to the angle between lines drawn through the long axis of the talus & 1st metatarsal (Wheeless, 2012). The angles abducted from the median as negative so that any adductus deformity is measured in positive values for convenience (Simons, 1985). Its normal range is from 0 to - 20 degrees (Wheeless, 2012). The calcaneal-fifth metatarsal angle between two lines: 1st line is parallel to the lateral border of the calcaneus. Second line represents the longitudinal axis of the fifth metatarsal (Dawoodi and Perera, 2012). It is an age dependent angle, decreasing significantly with age in children (Van der Wilde, 1988; Laaveg and Ponseti, 1980; Pettersson and Ringertz, 1991).

Functional assessment

The PDMS-2 was used to estimate the child's overall competence relative to peers, or to evaluate his or her gross motor abilities (Folio, 2000).

Figure 2. Anterior–posterior view radiograph with the marked talocalcaneal angle, the calcaneo-fifth metatarsal angle, and the talo-first metatarsal angle

Standardized tests have permitted therapists and other professionals to develop more scientific approach to

assessment (Richardson, 2005). Each child was individually evaluated for the gross motor scale (locomotion). The child was in a comfortable position and received clear explanation about the procedures of the test (Folio, 2000). The PDMS-2 is based on scoring each item as 2, 1, and 0. The scoring of each item was based on the on the child's performance and specific criteria for each item.

For treatment

Casting group

The children in this group were treated with short-leg serial plaster casting which was applied by a single pediatric orthopedist. Before applying the cast, the calcaneus was held and the forefoot bent laterally over the fulcrum of the finger on the lateral wall of the calcaneus. Care was taken to avoid creating valgus moments on the heel when applying an abduction force on the forefoot (Herzenberg, 2013). Plaster cast was changed biweekly for four casts (Staheli, 1994). Moderate pressure was used during application of the cast to maintain the circulation. Layers of cotton wool were applied on both malleoli of the ankle to avoid the pressure sore. The parents were instructed to contact the principal investigator if they observed any swollen or bluish colouration of the toes, any unusual crying of the child or complaining of pain.

Strapping group

All the children in this group have received a selected exercise program and strapping of the feet which were conducted by the principle investigator.

Exercise program: The program lasted for 1 hour/5 times per week for successive 8 weeks. It included the following:

- Rhythmic and repeated gentle manipulation: The knee joint was maintained in 90 degrees flexion to prevent any damage to the tibial or fibular epiphysis as well as the knee joint. The principal investigator was stabilizing the heel and gently stretching the forefoot towards the abduction. Stretching was maintained for 30 seconds (sec) followed by 30 sec relaxation and repeated for 5 times/ session.
- Manual stimulation of the foot on the lateral border from heel to toe by ice application, scratching followed by stimulation of the lateral compartment of the leg from heel to head of fibula. It was done 10 times/ session.
- Standing with both feet: While the child was standing with both feet held on the ground; the principal investigator was locking the child's knees and slowly tilt him forward, backward and to each side. It was done for 5 min.
- Step standing: While the principal investigator was standing behind the child, the child was encouraged to shift his weight forward and backward. This was done for 5 min.
- Single leg stance with assistance. The child is standing on exercise mattress. The principal investigator sat behind and elevated the child's leg and asked the child to maintain standing balanced on the other leg for 5 min for each leg alternately.
- Standing on a declined surface" by using wedge". The child was standing on wedge towards the descending direction. The principal investigator asked the child to maintain balanced standing in declined direction for 5 min.
- Stoop and recover while the principal investigator was locking the child's knees. it was done for 5 min.
- Gait training in open environment: Obstacles were used including rolls and wedges with different sizes and heights; the child was encouraged to walk forward, backward and sideways. It was done for 10 min.

Strapping

It was applied after the exercise program to maintain the feet in the corrected position. A 2.5 cm width non-allergic and non-elastic white tape (Jaybird and Mais EXI), tincture of benzoin compound (TBC), cotton wool, methylated spirit and a pair of scissors were used. The parent was asked to stabilize the child's limb while the principal investigator applied the procedures to one foot then to the other one (Figure 3) (Turner and Merriman, 2005). The child's limb was cleaned from the lower third of the leg to the toes to avoid sepsis by a cotton wool soaked in methylated spirit. After that, TBC was applied to prevent the skin excoriation and improve the adherence of the plaster. The tape was cut into four strips of appropriate lengths. Strapping began by holding the foot in the corrected position gained after manipulation and exercises. The principal investigator applied the first strip from the lateral border of the midpoint of the leg down under the heel then along the lateral border of the foot. The second strip was applied from the medial border of the midpoint of the leg down under the heel then along the medial border of the foot. While maintaining the forefoot in the corrected position, the third strip was applied over the dorsum of the forefoot from the medial border to the lateral border then under the sole of the foot back to the medial border again. The fourth strip was applied circumferentially around the leg at the points of attachments of the first and second strips. Each parent was trained by the author for the taping (Austin and Brett, 1994). The strapping was applied smoothly, with moderate pressure and without wrinkles to avoid the skin breakdown.

Figure 3. Taping of the foot

The tape was applied for 22 hours daily removing only during the exercise program. A tape cutter or bandage scissors were used for safe, fast removal of the tape. The tape was removed carefully by peeling it back on itself, and pushing the skin

away from the tape. The skin was checked for damage and lotion was applied to restore skin moisture. The parents were instructed to contact the principal investigator if they observed any swollen or bluish colouration of the toes, any unusual crying of the child or complaining of pain. Also, they were instructed to prevent the strapping from being wet by water or any other fluid and wore their children the reverse shoes with strapping.

Statistical analysis

The collected data of both groups were statistically analyzed. Descriptive statistics were done in the form of mean and standard deviation (SD) of all measuring variables in addition to the age, weight and height. Paired t-test was run to compare the pre and post treatment mean values of all measuring variables within each group. Unpaired t-test was used to compare the pre and post treatment mean values of all measuring variables between both groups. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through SPSS (Statistical Package for Social Sciences) version 20.

RESULTS

Baseline characteristics of the subjects

There were no significant differences at baseline characteristics of the subjects (age, weight and height) of both groups ($p > 0.05$) as presented in Table 1.

Table 1. Baseline characteristics of the subjects

Variable	Casting group	Strapping group	t-value	p-value
Age (years)	2.50 ± 0.36	2.67 ± 0.29	1.424	0.165
Weight (kg)	13.5± 1.50	12.9 ± 1.63	1.049	0.303
Height (cm)	88.20 ± 2.10	88.90 ± 1.96	0.943	0.353

Data are expressed as mean ± SD *P*-value: level of significance

Radiological examination and functional activity

Statistical analysis showed no significant differences when comparing the pre treatment mean values of the radiographic measurements and PDMS-2 of both groups ($p > 0.05$), presented in table 2. No significant differences were recorded between both groups when comparing the post treatment mean values of the radiographic measurements ($p > 0.05$) while there were significant differences in PDMS-2 in favor of the strapping group ($p < 0.05$) which presented in table 3 and demonstrated in figures 4 and 5.

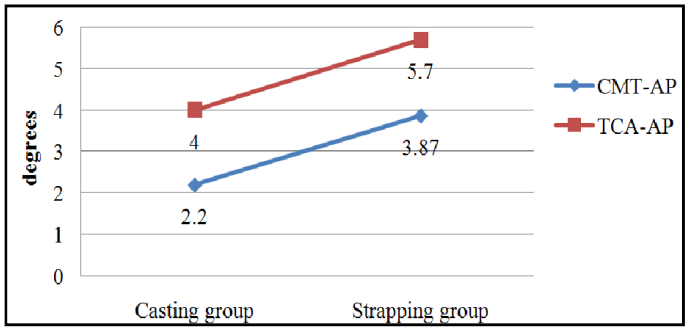

Figure 4. Post treatment radiological examination of both groups

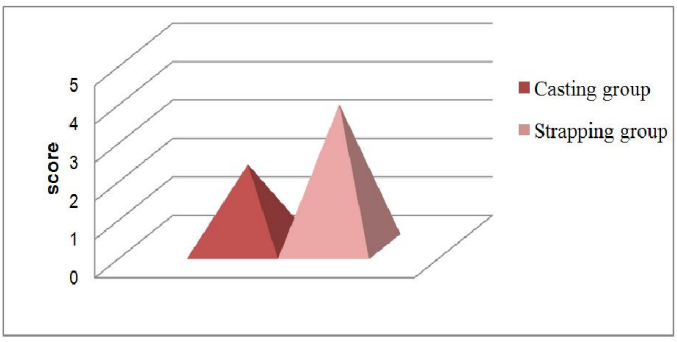

Figure 5. Post-treatment mean values of functional activity of both groups

The measurements for the casting group both pre and post treatments are presented in table 4. Significant differences were recorded when comparing the pre and post treatment mean values of the AP calcaneal-fifth metatarsal angle and AP talo-first metatarsal angle ($p < 0.05$).

Table 2. Pre treatment radiologic examination and functional activity of both groups

Variable	Casting group	Strapping group	t-test	*p*-value
TCA-LAT (degrees)	43± 1.850	42.33±1.165	1.187	0.245
TCA-AP (degrees)	33 ± 1.195	32.53 ± 1.187	1.606	0.131
CMT-AP (degrees)	22.60 ± 2.131	23.80 ± 1.207	-1.871	0.820
TMT-AP (degrees)	25.60 ± 1.056	26.13 ± 1.60	-1.658	0.120
Functional activity	2.12 ± 0.063	2.13 ± 0.091	0.349	0.729

TCA-AP, Talocalcaneal angle in anteroposterior view. TCA-LAT, Talocalcaneal angle in lateral view. TMT-AP, Talo-first metatarsal angle in anteroposterior view. CMT-AP, Calcano-fifth metatarsal angle in anteroposterior view *Significant at $P < 0.05$

Table 3. Post treatment radiologic examination and functional activity of both groups

Variable	Casting group	Strapping group	t-test	*p*-value
TCA-LAT (degrees)	43.50 ± 1.97	42.90 ± 1.193	1.009	0.322
TCA-AP (degrees)	32.20 ± 1.320	31.93 ± 1.223	0.880	0.389
CMT-AP (degrees)	2.20 ± 0.775	3.87 ± 3.226	-1.856	0.085
TMT-AP (degrees)	4 ± 1.464	5.70 ± 2.086	-1.835	0.088
Functional activity	2.14 ± 0.080	3.70± 0.390	15.176	0.0001*

TCA-AP, Talocalcaneal angle in anteroposterior view. TCA-LAT, Talocalcaneal angle in lateral view. TMT-AP, Talo-first metatarsal angle in anteroposterior view. CMT-AP, Calcano-fifth metatarsal angle in anteroposterior view *Significant at $P < 0.05$

Table 4. Pre and post treatment radiologic examination and functional activity of the casting group

Variable	Pre	Post	t-test	*p*-value
TCA-LAT (degrees)	43± 1.850	43.50± 1.97	0.717	0.479
TCA-AP (degrees)	33 ± 1.195	32.20 ±1.320	2.037	0.061
CMT-AP (degrees)	22.6 ± 2.131	2.20 ± 0.775	31.586	0.0001*
TMT-AP (degrees)	25.6 ± 1.056	4 ±1.464	36	0.0001*
Functional activity	2.12 ± 0.063	2.14 ± 0.080	0.761	0.452

TCA-AP, Talocalcaneal angle in anteroposterior view. TCA-LAT, Talocalcaneal angle in lateral view , TMT-AP, Talo-first metatarsal angle in anteroposterior view. CMT-Ap, Calcano-fifth metatarsal angle in anteroposterior view * Significant at $P < 0.05$

There was no significant change PDMS-2 after treatment as well as no significant changes in the heel valgus, as measured by the lateral and AP talocalcaneal angle ($p > 0.05$). The measurements for the strapping group both pre and post treatments are presented in table 5.

Table 5. Pre and post treatment radiologic examination and functional activity of the strapping group

Variable	Pre	Post	t-test	*p*-value
TCA-LAT (degrees)	42.33 ± 1.165	42.90 ± 1.193	1.324	0.192
TCA-AP (degrees)	32.53 ± 1.187	31.93 ± 1.223	1.871	0.082
CMT-AP (degrees)	23.8 ± 1.207	3.87 ± 3.226	20.378	0.00001*
TMT-AP (degrees)	26.13 ± 1.60	5.70 ± 2.086	33.523	0.00001*
Functional activity	2.13 ± 0.091	3.70 ± 0.390	15.183	0.001*

TCA-AP, Talocalcaneal angle in anteroposterior view. TCA-LAT, Talocalcaneal angle in lateral view. TMT-AP, Talo-first metatarsal angle in anteroposterior view. CMT-AP, Calcano-fifth metatarsal angle in anteroposterior view * Significant at $P < 0.05$

Significant differences were recorded when comparing the pre and post treatment mean values of the AP calcaneal-fifth metatarsal angle, AP talo-first metatarsal angle, and PDMS-2 ($p < 0.05$). There was no significant change in the heel valgus, as measured by the lateral and AP talocalcaneal angle ($p > 0.05$).

DISCUSSION

Metatarsus adductus is the most common lower extremity pediatric deformity encountered by the pediatric physician. Parents most commonly wait until they are 10-15 months of age, after walking has begun. Unfortunately, most of the deformities by this age have become rigid in nature and do not respond to conservative treatment as favorably as those treated earlier (The Podiatry Institute. Bracing devices for pediatric foot and leg deformities, 1995). This would prompt a treatment protocol starting with serial casts. Serial casting is also indicated in cases which are either severe or appear not to be resolving as the child gets older. Ideally, serial cast treatment should start before walking age but this may not be possible in all cases (Joseph, 2009). Although there are several studies involving taping techniques for knee and ankle problems, the number of studies regarding taping for MTA is limited.

Therefore, this study was conducted to compare the effects of the serial plaster casting to that of the combined treatment program consisting of both a rigid strap taping and selected exercise program in correcting MTA of toddler children. Cases resistant to serial casting may require surgery and the options include release of the abductor hallucis tendon, medial mid-foot/tarso- metatarsal joint capsulotomy or osteotomy of the medial cuneiform and cuboid in the older child (Wenger and Leach, 1986).Surgery is not recommended because surgical complications are frequent (Staheli, 1994). Most of the time, surgery is delayed until the child is between 4 and 6 years old (Hosalkar *et al.,* 2011). Therefore, the selection of age group was ranged from 2 to 3 years. There were significant differences when comparing the pre and post treatment mean values of radiological examination ($p < 0.05$) of both groups as well as when comparing the post treatment mean values of both groups without significant differences in the lateral and AP talocalcaneal angle ($p > 0.05$) indicating no heel valgus angulations (Van der Wilde *et al.,*1988).

In a study conducted by Katz (Katz *et al.,* 2013) on sixty-five infants with moderate and severe inflexible MTA to evaluate the effect of a below-knee plaster cast. The deformity was corrected in 6-8 weeks in all cases. At 2 to 6 years follow-up, the correction was maintained in all children with moderate deformity, six had a moderate deformity while one had severe deformity. So, it was concluded that a below-knee plaster cast was effective in the treatment of MTA. In a study conducted by Herzenberg and Burghardt (Herzenberg and Burghardt, 2013) concluded that, the Bebax orthosis and serial casting, when applied correctly, they could give equally satisfactory clinical results in the treatment of resistant MTA in infants under the age of 9 months. No significant improvement in the functional activity of the casting group ($p > 0.05$) could be explained by (Bohne, 1987) who mentioned that the feet were extremely rigid in a corrected position following the period of casting. They regained flexibility in the successive three years. (Allen *et al.,* 1993) added that, treatment with serial casting is time-consuming, costly, and interferes with bathing and hygiene.

The significant improvement in the functional activity of the strapping group ($p < 0.05$) could be attributed to the combined effect of the strapping and the selected exercise program. This is supported by (Wright *et al.*, 2014) who stated that, the primary purposes for tape application are to provide additional support, stability and compression for the affected body parts. Stretching exercises may also prove helpful. By exercising the child's foot, the muscles which turn the foot outward may be stimulated (Children of Alabama, Metatarsus adductus). The functional weight-bearing exercise programs provide an improved and more consistent proprioceptive feedback that in turns improves the control of movement (Palisano *et al.,* 2001). Proprioceptive input to central nervous system is very important for conscious awareness of joint position sense and motion so it is important to design the exercise programs to improve the kinesthetic awareness (Loudon *et al.,* 2009).

Potential complications of casting, such as loss of dermal integrity, circulatory compromise, creation of iatrogenic deformity, emotional distress of the child and parent can be avoided by using the brace since the limb can be monitored daily (The Podiatry Institute, Bracing devices for pediatric foot and leg deformities, 1995). In a study conducted by (Bayar *et al.,* 2011) to investigate the effect of a combined treatment program consisting of both taping and exercise in correcting the hallux valgus. It was concluded that both taping and exercise had more beneficial effects than exercise alone on hallux valgus angle, foot pain and walking ability.

Conclusion

The present study was conducted to compare between two different treatment approaches (serial plaster cast and a combined treatment program consisting of both a rigid strap taping and selected exercise program) in correcting resistant metatarsus adductus in toddler children. Based on the obtained results, we could conclude that rigid strapping tape together with a selected exercise program is an excellent decision for correcting resistant metatarsus adductus in toddler children.

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