Evaluating the biomechanics of the paediatric foot in Turner syndrome: a case report

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Abstract

Background: Turner syndrome is a genetic disorder which can present clinically with multiple concurrent co-morbidities which are reported to include foot pathology. This case report will present a girl with Turner syndrome who was referred for podiatric assessment and will explore the application of optoelectronic stereophotogrammetry in the biomechanical assessment of the foot. **Method**: A four segment foot model utilising 9mm reflective markers was applied to the foot and lower limb in order to track motion at the tibia, rearfoot, forefoot and hallux. Three-dimensional motion analysis was then conducted using a ten-camera VICON 612 system (Vicon Motion systems Ltd, Oxford, UK). **Results:** The kinematic results presented in this case study illustrate evidence of excessive foot pronation throughout the gait cycle. **Conclusion:** Whether excessive pronation is a general characteristic of foot function in Turner syndrome remains to be confirmed but the findings presented suggest that a comprehensive evaluation of foot kinematics in patients with Turner syndrome may be warranted.

Introduction/Background

Turner syndrome is a genetic disorder associated with complete or partial absence of the X chromosome and is reported to occur in approximately 50 per 100,000 liveborn girls[1]. The syndrome can result in multiple concurrent co-morbidities which cover a range of body systems and consequently require care from a range of medical professionals[1]. The role of the podiatrist within the multidisciplinary team has been poorly recognised in the literature even though podiatric intervention is warranted for these girls[2]. In a descriptive study looking at foot problems in Turner Syndrome, Findlay et al[2] evaluated the feet of 23 girls diagnosed with the syndrome. This study characterised the foot in Turner syndrome as short, broad, excessively pronated and predisposed to foot pathology. Furthermore, this study also suggested that a number of predisposing factors in these girls can result in foot pathology and thus podiatric examination should form part of their multidisciplinary care.

The clinical assessment of the paediatric foot is often limited to subjective, static evaluation but with advances in optoelectronic systems it is now possible to conduct comprehensive assessment of the foot during gait. Three-dimensional biomechanical analysis can offer a number of advantages when used in clinical assessment and allows for quantitative kinematic and kinetic data to be incorporated into clinical decision making. Recently a number of foot models have emerged which allow for a greater understanding of foot function during gait[3,4,5]. However it is out with the remit of this report to discuss these and the reader is referred to the literature for further information[6]. The aim of this case report is to present a three-dimensional, biomechanical assessment of the foot in a girl with Turner syndrome.

Case Report and Three-Dimensional Analysis

A twelve year-old female was referred for podiatric assessment following parental concerns regarding the position of their daughter's feet. On initial examination typical characteristics of the foot in Turner syndrome were identified. The feet were broad and large for skeletal height (UK size 8), they were hyperextended at the interphalangeal joints of both halluces and brachymetatarsia of the left foot with brachymetapody of the 4th and 5th toes.

On static weight bearing assessment there was flattening of the medial longitudinal arch and a presentation of a planus foot-type. The Foot Posture Index (FPI – 6) was used to score the foot and a score of 10 was recorded for the left foot (indicative of a highly pronated foot) and 9 for the right (indicative of a pronated foot). Observational gait analysis revealed the feet to be pronated through the stance phase of gait and the global gait pattern tentative and apropulsive with a reduced cadence and increased periods of double-limb support duration. At the time of assessment there were no concerns regarding musculoskeletal pain or pathology.

Following chair-side assessment 9mm reflective markers were applied to a number of sites on the lower limb and foot. A Vicon plug-in gait marker set, similar to Helen Hayes[7] was applied to the lower limbs and the Oxford Foot Model[8] was applied to the dominant foot (right foot) by the same investigator (AI). The markers were placed at the following landmarks: lateral knee, lateral head of the fibula, tibial tuberosity, the anterior aspect of the shin, lateral malleolus, medial malleolus, proximal posterior calcaneus, distal posterior calcaneus , a peg marker placed on the posterior calcaneus, lateral calcaneus, sustentaculum tali, 1st metatarsal- proximal dorsal, 1st metatarsal- distal medial, 5th metatarsal- proximal lateral, 5th metatarsal- distal lateral, mid-point of the distal heads of the 2nd and 3rd metatarsals and the hallux- at the proximal end of 1st phalanx

The Oxford Foot Model (OFM) defines the foot as four segments and measures relative motion of the tibia, hindfoot, forefoot and hallux. Three-dimensional analysis was conducted using a ten-camera VICON 612 system (Vicon Motion systems Ltd, Oxford, UK) to track the joint trajectories of the 9mm reflective markers applied to the foot and lower limb. Two force plates (Kistler, Instruments AG, Switzerland) collected ground reaction forces to measure kinetics during the gait cycles however this data is not presented.

Following a static calibration capture, the subject was the asked to walk at a comfortable, self-selected speed along the pre-determined eight metre walkway. Ten successful trials were captured and a successful trial was defined when the foot was fully loaded on the force platform. The data was processed in Vicon Polygon software to allow the normalization of joint motions over 100 time points from heel strike to heel strike, thus capturing stance and swing phase. Lower limb joint and segmental kinematics were calculated based on the Joint Coordinate system[9] and filtered using a Woltring filter with mean square error value of 20.

Results of kinematic analysis

Table 1 summarises the data captured for the case and presents mean segmental angles (˚) for the forefoot-hindfoot angle , forefoot-tibia angle, hindfoot-tibia angle and hallux- forefoot angle throughout the gait cycle.

Heel Strike (0%)

As presented in table 1, at initial heel contact both the forefoot (forefoot-tibia angle) and hindfoot segments (hindfoot-tibia angle) were everted relative to the tibia. In addition, the forefoot relative to both the hindfoot (forefoot-hindfoot angle) and tibia (forefoot-tibia angle) were dorsiflexed and adducted. Figure 1 represents the movement of the forefoot relative to the tibia throughout the gait cycle.

Toe Off (61%)

At toe off the forefoot relative to the hindfoot segment (forefoot-hindfoot angle) was dorsiflexed, inverted and adducted. However, both the forefoot and hindfoot segments relative to the tibia were plantarflexed, everted and adducted. As expected the hallux exhibited the greatest dorsiflexion at toe off (RHXFFA).

Heel Strike (100%)

The same kinematic profile seen on initial heel contact was repeated between all segments at heel strike (100%). Both the forefoot and rearfoot segments again were everted relative to the tibia.

Further analysis of the foot is presented in Table 2 which presents the range of motion for the gait events and maximum value for joint angles.

Discussion

The purpose of this case report was to present a 3-dimensional analysis of the foot in a child with Turner syndrome. Following kinematic analysis it can be observed that mean segmental angles (table 1) of the forefoot and hindfoot segments functioned in an everted alignment throughout the stance phase of gait. At heel strike the foot would be expected to be inverted and then move into pronation throughout the loading response but in this instance the rearfoot is in an everted position at initial contact. The findings also suggest that the foot remained in a pronated position throughout the stance phase (see Figure 1) and at propulsion. This is an important consideration as the foot would be expected to act as a rigid lever at propulsion and may, in this instance, reflect the apropulsive gait demonstrated during clinical examination. This excessive and prolonged pronation could be considered pathological and warrants observation and quite possibly intervention[10].

With this case report it isn't possible to extrapolate the findings to the population of girls with Turner syndrome, but to further understand the biomechanics of the foot in Turner syndrome comparison with other data is necessary. Studies utilising the OFM in the assessment of the paediatric foot are limited but some work has been conducted to determine reliability of the model[3]and also to characterise the foot in Cerebral Palsy[11]. In comparison to Stebbins et al[3] which was based on 15 healthy children (average 9.5 years) this case study demonstrated considerably larger ranges of motion at the forefoot and rear-foot with respect to the tibia in all three planes. However forefoot to rear-foot motion was comparable with this data. Maximal values differed across all segment to segment comparisons with Stebbins et al[3] data indicative of an off-set due to foot deformity in the static pose, especially true for forefoot pronation and rear-foot eversion. In line with the work presented by Stebbins et al[3] each joint angle obtained throughout the dynamic trials were not referenced to the neutral position during the static trial. Whilst this may increase the variability in multi-subject/session tests it allows measurement of foot deformity which may cause non-zero joint angles in the static trial.

The kinematic results presented with this case study indicate that a pronated foot type was evident during static stance (based upon the FPI-6 score) and throughout the gait cycle. These findings are of interest and suggest comprehensive evaluation of the foot in girls with Turner syndrome is warranted which could support intervention. Whether a pronated foot is a general characteristic of the foot in Turner syndrome remains to be confirmed and therefore, further investigation is required.

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