

WEARABLE SENSOR-BASED GAIT CLASSIFICATION IN IDIOPATHIC TOE WALKING ADOLESCENTS

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ABSTRACT

Idiopathic toe walking on the balls of the feet is commonly found in children. Many toddlers who are just beginning to walk show signs of toe walking, but when toe walking persists after two years of age, the child's risk of falling increases as well as the risk of other developmental delays. Idiopathic toe-walking is estimated to occur in 7 to 24% of children. In order to address the problem of toe walking and assess improvements due to intervention, one needs to identify heel-toe gait versus toe-toe gait in natural environments of idiopathic toe walkers. The aim of this study was to investigate if learning algorithms utilizing triaxial accelerometers and gyroscopes from wearable sensors could detect and differentiate heel-toe gait versus toe-toe gait. In this study, 5 adolescents (13± 5 years) patients with idiopathic toe walking characteristics wore inertial sensor at L5 – S1 joint. New interventions can be designed for idiopathic toe walking population, but currently, it is a challenge to quantify the efficiency of toe-walking intervention. In recent times, with the advancement of machine learning classification methods and powerful computing, longitudinal data from wearable sensors can be used to accurately classify gait abnormalities. The aim of this study was to investigate machine learning methods to classify toe-toe walking versus heel-toe walking using data from a single inertial sensor. We found that k-means clustering was successful in differentiating toe walking with that of typical walking signals. We found that some of the linear variability based features such as standard deviation, Root Mean Square (RMS), and kurtosis contained most of the variability among the data and could therefore distinguish toe-toe gait versus heel-toe gait through clustering. The k-means cluster provided an 82% accuracy score with a specificity of 83% and sensitivity of 86%. We further utilized Recurrent Convolution Neural Network (RNN) such as Long Short-Term Memory (LSTM). The LSTM model was another classification method that was used to distinguish between toe-toe gait and heel-toe gait. Wearable sensors integrated with machine and deep learning algorithms have the capability to transform current on-going therapy methods and monitor patients longitudinally for their improvement in gait. These novel learning-based techniques could successfully classify toe walking gait and help in estimating the efficacy of the treatment in idiopathic toe walking adolescents.

Keywords: idiopathic tow walkers (ITW), toe-toe gait, heel-toe gait

INTRODUCTION

Toe walking is usually associated with cerebral palsy, muscular dystrophy, autism spectrum disorders, and global developmental delay[1]. Idiopathic Toe Walkers (ITW) are normally children (above the age of 3 years) without a medical condition who are observed with a condition of toe walking[2]. In fact, toe walking is a normal variation in gait during child development upto the age of 3 years[2], and the complete maturation of ankle dorsiflexion during the foot contact is usually at the age of five years[3, 4].

Pediatric orthopedic surgeons and physical therapists define toe walking as symptomatic of decreased ankle range of motion and an inability to make a heel strike during the initial phase of foot contact[5]. Idiopathic toe-walking is estimated to occur in 7 to 24% of children[6, 7]. In order to study toe-walking severity and design an intervention for gait rehabilitation one has to identify when and for how much duration the toe walking is occurring in ITW. Machine learning has been applied in gait research to classify fatigue[8] and estimate minimum toe clearance[9]. Deep learning is a category of learning algorithms which have multiple non-linear processing neural layers. Deep learning methods have been found to out-perform machine learning algorithms [10-12]. It is not known whether machine learning