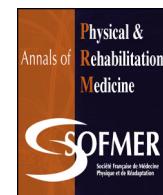




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Original article

## Rehabilitation improves walking kinematics in children with a knee varus: Randomized controlled trial

**Q1** Amir Ali Jafarnezhadgero <sup>a,\*</sup>, Mahdi Majlesi <sup>b</sup>, Hojat Etemadi <sup>b</sup>, D.G.E. Robertson <sup>c</sup>

<sup>a</sup> Department of Physical Education and Sport Sciences, Faculty of Educational Science and Psychology, University of Mohaghegh Ardabili, Ardabil, Iran

<sup>b</sup> Department of Sport Biomechanics, Faculty of Humanities, Islamic Azad University, Hamedan Branch, Hamedan, Iran

<sup>c</sup> School of Human Kinetics, University of Ottawa, Ottawa, Ontario, Canada

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### ARTICLE INFO

#### Article history:

Received 17 September 2017

Accepted 30 January 2018

#### Keywords:

Genu varus

Gait

Lower limb

Joint angle

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### ABSTRACT

**Background:** Previous studies have demonstrated increased medial stresses in knee varus alignment. Selecting a suitable treatment strategy for individuals with knee malalignment should be a priority.

**Objectives:** We aimed to investigate the effects of a 16-week corrective exercise continuum (CEC) program on 3-D joint angles of the dominant and non-dominant lower limbs in children with genu varus during walking.

**Methods:** Overall, 28 male children with genu varus (age range 9–14 years) volunteered to participate in this study. They were randomly divided into 2 equal groups (experimental and control). The participants of the experimental group received CEC for 16 weeks. 3-D gait analysis involved using a Vicon Motion System. Paired and independent sample t-tests were used for within- and between-group comparisons, respectively.

**Results:** For the experimental group, comparison of pre- and post-test joint kinematics of the dominant lower limb revealed that CEC decreased the peak ankle dorsiflexion angle by 26% ( $P = 0.020$ ), peak foot internal rotation angle by 53% ( $P = 0.001$ ), peak knee internal rotation angle by 40% ( $P = 0.011$ ), peak hip abduction by 47% ( $P = 0.010$ ), and peak hip external rotation angle by 60% ( $P = 0.001$ ). In contrast, peak knee external rotation angle of the dominant limb was increased after the training program by 46% ( $P = 0.044$ ). For the non-dominant lower limb, CEC decreased the peak ankle inversion by 63% ( $P < 0.01$ ), peak ankle eversion by 91% ( $P < 0.01$ ), peak foot internal rotation by 50% ( $P < 0.01$ ), peak knee internal rotation by 29%; ( $P = 0.042$ ), peak hip abduction angle by 38% ( $P < 0.01$ ), and peak hip external rotation angle by 60% ( $P < 0.01$ ).

**Conclusions:** CEC therapy reduced excessive foot and knee internal rotations as well as excessive hip external rotation during walking in children with genu varus.

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## 1. Introduction

Knee osteoarthritis (OA) is one of the most common and important diseases affecting about 10% of the adult population [1]. The distribution of tibiofemoral compressive forces between the medial and lateral compartments could be affected by frontal-plane joint position and affect degeneration of biological knee joint tissues [2]. Laboratory and cadaver studies have demonstrated

increased medial stresses in knee varus alignment [3], which may result in accelerated articular cartilage degeneration. Therefore, selecting a suitable treatment strategy for individuals with knee malalignment should be a priority.

The treatment of varus malalignment of the knee is likely to benefit from an increased understanding of the biomechanical risk factors associated with knee injuries. In total, 13% of children with age 11 years showed knee varus deformity that needed treatment to prevent secondary deformity in adulthood [4]. Previous studies have investigated biomechanical changes during walking in children with genu varus (without knee OA) as compared with healthy controls [5,6]. Varus alignment of the knee in healthy children is associated with abnormally increased internal foot

**Abbreviations:** SMR, Self-myofascial release; MAA, mechanical axis angle; d, effect size; Q angle, quadriceps angle.

\* Corresponding author.

E-mail address: [amirali.jafarnezhad@gmail.com](mailto:amirali.jafarnezhad@gmail.com) (A.A. Jafarnezhadgero).

placement and increased internal knee rotation during the stance phase of walking [5]. Bias of muscle activation to knee external rotators and lateral knee joint muscles may decrease knee joint internal rotation [7] and therefore reduce medial knee joint load. However, this was not evaluated from a scientific standpoint.

Kean et al. [3] argued that change in quadriceps strength (12-week quadriceps strengthening program) did not predict the change in peak vertical ground reaction force or average rate of loading (changes in quadriceps strength explained 3% of the variance in the change in maximum rate of loading) in individuals with medial knee OA and varus alignment. Another study reported that a quadriceps strengthening protocol had no significant effect on knee adduction moment, considered a main risk factor for OA [8]. However, we have a dearth of information regarding the impact of corrective exercise programs on joint kinematics of the lower extremities in children with genu varus. Further study is needed to assess the effects of different scientific training protocols on biomechanical variables of walking in these children.

Although childhood is the appropriate time to implement therapeutic interventions such as corrective protocols, unfortunately, most training programs do not feature the proper treatment guidelines for children [9]. Among various corrective exercise programs, the corrective exercise continuum (CEC) programming strategy is considered a popular and effective therapy modifying the anatomical alignment of the extremities [9]. The CEC includes 4 primary phases [9] with the aim of releasing tension of overactive neuromyofascial tissues (via self-myofascial release [SMR] techniques) [10–12], increasing the extensibility of neuromyofascial tissues [13,14], reeducating or increasing the activation of underactive tissues (by isolated strengthening exercises and positional isometric techniques) [9], and finally retraining the

collective synergistic function of all muscles via progressive movements [9].

Previous studies demonstrated several positive effects of corrective exercise with suitable dosage for improving musculoskeletal disorders [15,16]. To the best of our knowledge, no study has investigated correcting gait kinematic alterations (3-D lower limb joint angles) in children with genu varus malalignment with a training protocol involving CEC.

The aim of this study was to assess the effectiveness of a 16-week CEC programming strategy on 3-D joint angles of the dominant and non-dominant lower limbs during walking in children with genu varus. We hypothesized that with improved strength of the knee external rotators and the lateral knee muscles resulting from using CEC, children with genu varus could have lower foot internal rotation as well as lower knee internal rotation in both limbs during walking.

## 2. Material and methods

### 2.1. Participants

This study was an open-label randomized controlled trial. We used G\*Power 3.1 (for statistical power analysis) to calculate an *a priori* power analysis of the test family (*t*-tests) and the respective statistical test based on a related study that examined between-group differences in walking kinematics (i.e., hip external rotation) in individuals with and without genu varus [6,7]. With a statistical power of 0.8 at an effect size of 0.95 with an alpha level of 0.05 and allocation ratio of 1, we needed at least 14 participants for each group [17].

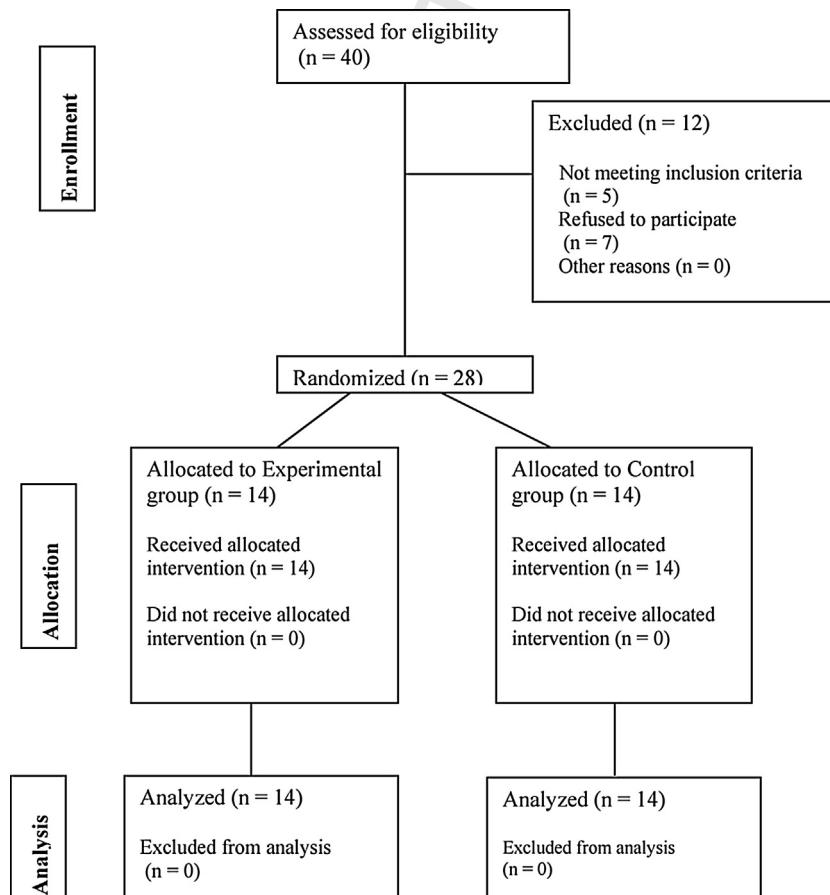


Fig. 1. Flow of the children in the study.

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