Effects of Genu Varum Deformity on Postural Stability

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Key words
- genu valgum
- genu varum
- balance indices
- falling risk

Abstract

It is well known that any balance control disturbance can increase the risk of injury during sport activities. Knee deformities such as genu valgum and genu varum may perturb the line of gravity passing the lower limb joints and so disturb dynamic and static balance indices. This study was designed to investigate the effects of genu valgum and genu varum deformity on the static and dynamic balance indices. 90 non-athletic female university students (age: 21.8±1.75 years, weight: 55.8±9.6 kg, height: 161.3±11.9 cm) were assigned in one of the 3 experimental groups; normal knee (n=30), genu varum (n=30) and genu valgum (n=30), according to their knee conditions. Static and dynamic overall stability index (OSI), anteroposterior stability index (APSI), mediolateral stability index (MLSI) and falling risk were evaluated by the Biodex balance system. No significant difference was seen among these groups in terms of dynamic and static OSI and APSI, while significantly higher falling risk and lower stability was found in the genu varum group compared to the normal groups in term of dynamic and static MLSI ($p<0.05$). The results showed that genu varum deformity may increase the normal postural sway in the mediolateral direction and also increase falling risk.

Introduction

Postural control is the ability to maintain equilibrium and orientation in a gravitational environment [14]. It has been shown that postural control may be affected by genu valgum and genu varum deformities during the induced supination and pronation moments on the ankle and foot joints [29],which can result in the changing of the quality of postural control [8].

Genu valgum (knock knee) and genu varum (bow leg) are commonly reported as knee joint deformities and are more frequent in women [17]. In normal bilateral standing, the mechanical axis or weight bearing line of the lower extremity will pass through the centre of the knee joint, so that the weight distributes midway between the medial and lateral knee compartments [16]. In genu valgum deformity, the weight bearing line is shifted towards the lateral compartment of the knee and as a result the compressive forces over this area will be increased. While in genu varum deformity, the weight bearing line is shifted towards the medial compartment and the compressive forces over the medial part of the knee will be increased [19]. This discrepancy may elevate the asymmetry of weight-bearing, cause postural instability [1] and challenge the postural control strategy during stance [9].

A poor postural control was reported in subjects with supinated or pronated feet during the single leg stance [28]. This may alter the Ground Reaction Force (GRF) within the frontal plane and change the Centre Of Pressure (COP) location on the plantar of the foot [29], which may disturb the balance control strategy during physical activities.

It has also been claimed that genu varum deformity would tend to cause an increase in subtalar pronation moment during the contact and also in the propulsion phases of walking, while a genu valgum deformity may cause some increase in subtalar pronation moment during the contact phase and an increase in subtalar supination moment during the early propulsive phase [29]. The increased subtalar pronation or supination moment may change the gravitation torque force on the foot and create stress over the longitudinal arch of the foot [18] and thus postural stability may be affected by foot type under both static and dynamic conditions [8].

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Bibliography
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Considering the influence of genu valgum and varum deformities on the knee joint mechanical axis deviation and also its effect on the foot supination or pronation moment, it seems that knee deformities may disturb the balance control strategy during physical activities. This balance disturbance may increase the risk of injury incidence during sport activities [15,21]. It has been claimed that an intact balance control strategy is necessary to prevent any injury during heavy physical activities such as sport activities [27]. As higher injury incidence was seen combined with poor postural control [21], the subjects with genu varum or genu valgum may be at high risk of injury during their sport activities. However, as no study has investigated the influence of these knee deformities on the quality of balance control, this study was designed to investigate the changes in static and dynamic balance indices in subjects with genu valgum or genu varum.

Method

A controlled cross-sectional trial was designed with assessor blinding to the experimental groups. The proposal was approved by the Ethical Committee of the Semnan University of Medical Sciences. The study has also been performed in accordance with the ethical standards of the International Journal of Sports Medicine [12]. 90 non-athletic female university students (age: 21.8 ± 1.75 years, weight: 55.8 ± 9.6 kg and height: 161.3 ± 11.9 cm) were invited to participate in the study (30 subjects with genu varum deformity; 30 subjects with genu valgum deformity; and 30 normal subjects).

Exclusion criteria: subjects with history of neuro-musculo-skeletal diseases, history of trauma or fracture in the lower limbs during the last year, professional athletes and other lower limb deformities were excluded from the study. All participants signed their informed consent forms and were familiarized with the study's procedure.

To evaluate the varus or valgus of the knee joint, the participants were asked to stand against the wall, bare foot, in an anatomical position, while their back, buttocks and both heels touched the wall. Then the subjects were asked to put their feet together. A gap of more than 3 cm between the 2 medial malleolus (ankle) was considered as genu valgum, while a gap of more than 3 cm between the 2 medial knee epicondyles was considered as genu varum [17,25] (Fig. 1). Then, the subjects were nominated to one of the experimental groups, according to their lower limbs alignment.

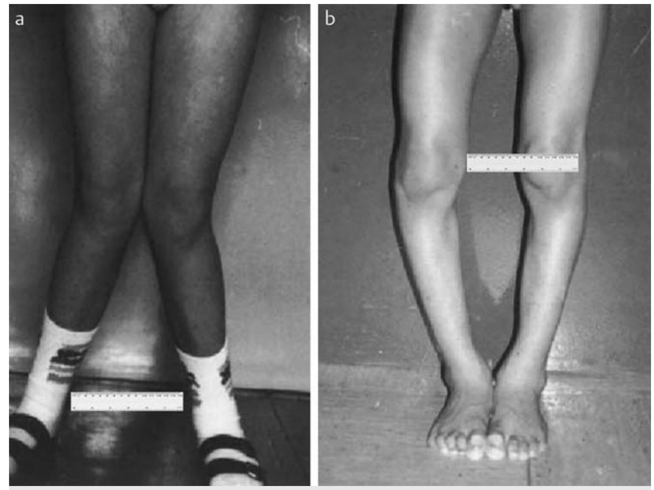

Fig. 1 A distance of more than 3 cm between 2 medial malleolus of the ankles was considered as genu valgum **(a)**, and a distance of more than 3 cm between 2 medial epicondyles of the knees was considered as genu varum **(b)**.

Data Collection

Instruments and procedure

A Biodex Balance System (BBS) was used to evaluate dynamic and static balance indices. Its great reliability for evaluating dynamic and static postural balance has been reported in previous studies [2,8], Its reliable measures were indicated by R = 0.94 (overall stability index), R = 0.95 (anterior-posterior stability index), and R = 0.93 (medial-lateral stability index) [7]. The device uses a circular platform that is free to move in the anterior-posterior and medial-lateral axes simultaneously. The BBS allows up to 20° of foot platform tilt and calculates 3 separate measurements: Medial-Lateral Stability Index (MLSI), Anterior-Posterior Stability Index (APSI) and Overall Stability Index (OSI), indicating the postural sway in the anterior posterior, medial-lateral directions and overall. A higher score than that stated in each index such as MLSI indicates poor balance. It is believed that the OSI score is the best indicator of the overall patient ability to maintain balance on the free platform [24].

In order to measure the OSI, APSI, MLSI scores, all participants wore long trousers to blind the assessor. The subjects were asked to step on the BBS platform with bare feet and assume a comfortable position. The position of the feet on the platform was different among the subjects. The exact position of the feet was detected by the graded surface of the platform and recorded in the software for further correction. The subjects were asked to maintain their feet positions on the platform throughout the test session. Before starting the test procedure, participants were trained for 1 min to adapt to the test procedure. Then, all participants performed 3 different test set-ups in a systematic order: 1) static, 2) dynamic and 3) falling risk conditions with eyes open. During the static balance test, the platform was locked under the feet, while during the dynamic test the platform was unlocked under the feet with stability levels ranging progressively from 6 (most stable) to 1 (least stable). After the static and dynamic balance tests, falling risk index was immediately evaluated by BBC for all subjects. During the falling risk test procedure, the platform was unlocked and was completely free to move in all directions (no progressive change in resistance). At all the stages of the balance test conditions, the assessor instructed the subjects to maintain their COP in the smallest of the concentric rings (balance zones) on the BBS monitor, named the A zone. Each of the test conditions was repeated 3 times; 20 s each with 15 s rest interval. The OSI, APSI, MLSI and falling risk index were calculated by the mean of COP displacement during 3 test trials. The machine calculated falling risk index and OSI by taking the COP displacement in the anterior-posterior (sagittal plane) and medial-lateral (frontal plane) into account, while APSI and MLSI were calculated from platform displacement in a sagittal plane and frontal plane, respectively.

Statistical analysis

The recorded mean values of balance and falling risk indices were normalized by dividing by the subject's height [6]. The normalized mean of static and dynamic OSI, APSI and MLSI and falling risk were compared between experimental groups by one-way ANOVA, and a Tukey statistical test with % 95 confidence coefficients and $\alpha < 0.05$ was used to reveal significant level between genu varum, genu valgum and normal groups. SPSS software version 17 was used to analyse the recorded data.

Results

No significant difference in the demographic data including age, height and weight was found between groups (Table 1). Table 2 shows the overall, anterior-posterior and medial-lateral stability indices during the static balance test in the experimental groups. Comparing the recorded balance index values showed no significant difference between groups in terms of OSI and APSI. However, a higher MLSI was seen in both genu valgum and genu varum groups, which was only significant in the genu varum group compared to the normal group (p = 0.036), Table 2.
The value of dynamic balance indices are shown in Table 3. No significant difference was found among groups in terms of OSI and APSI values, while a significant increase in MLSI was seen in the genu varum group, compared to the normal group (p = 0.031) .
A significant increase in the normalised falling risk index was found in the genu varum group compared to the control group (p = 0.03), while this increase was not considerably different from the genu valgum group (Fig. 2).

Table 1 Demographic data of subjects. Data are presented as means (SD) and p-value for all comparisons are p > 0.05, except the distances between the knees and the ankles, which were significantly different among groups (P < 0.0001).

Variables	Genu valgum (n = 30)	Genu varum (n = 30)	Normal (n = 30)
weight (kg)	59.10 (11.93)	52.55 (6.29)	55.65 (7.91)
height (cm)	160.60 (15.13)	163.20 (14.66)	160.00 (15.65)
age (year)	21.40 (1.93)	21.50 (1.32)	22.50 (1.82)
distance between the knees (cm)	0	6.1 (2.5)	1.3 (0.6)
distance between the ankles (cm)	5.6 (1.9)	0	1.6 (0.9)

Discussion

Our primary findings revealed that genu varum deformity may affect the postural sway index in the medial-lateral direction during both, static and dynamic balance measures, but has no effect on the OSI and APSI.
The process of maintaining the centre of gravity in the base of support has been known as the balance control process, which is used as an indicator for lower limb function assessment [16]. The intact balance control system is important and vital in preventing injury during the activities of daily life [5, 27]. The ability of balance control and to make postural alterations in response is essential to prevent injury [22]. Although the effect of ankle joint deformities on the dynamic and static postural control has been the subject of several studies, no investigation has been performed on the effects of varus and valgus knee deformity on the balance control protocols. This is especially important when considering that these knee deformities (especially genu varum) are commonly seen in elderly people who usually have falling problems [26].
The results of this study showed that the postural sway in the frontal and sagittal plane may not be affected by genu valgum deformity. This stability in the postural sway control was also seen in people with genu varum deformity, only in the sagittal plane (anterior-posterior direction), while their stability was perturbed in the medial-lateral direction (frontal plane). Perhaps the medial shift of line of gravity (LOG), in subjects with genu varum, may increase postural sway in the medial-lateral direction. This has also been shown by Anker and colleagues who stated that asymmetry weight bearing may increase the postural sway [1], as it has been shown , knee deformity in frontal plane may change the normal weight distribution on the knee joint [11], and also ankle joint [1]. It has been suggested that through increasing weight bearing asymmetry, the postural instability increased by reducing the efficiency of hip load/unload mechanisms and increasing the compensatory ankle moments, which may increase postural sway [1].
It has been shown that a genu varum deformity may cause some medial rotation in leg, which may turn to a pronation in subtalar and mid foot joint during weight bearing [20]. A neutral and normal structure of foot is necessary for its intact and precise

Table 2 Static OSI (overall stability index), APSI (anterior-posterior stability index) and MLSI (medial-lateral stability index) were normalized with subject's height (stability index/subject's height in cm) and expressed as 10^{-2}, mean (SD).

Static balance index	Genu varum (n = 30)	Genu valgum (n = 30)	Normal knee (n = 30)	Knee factor F-value	Tukey test P-value
OSI	0.38 ± 0.12	0.42 ± 0.21	0.35 ± 0.11	0.98	n. s.
APSI	0.25 ± 0.08	0.29 ± 0.19	0.25 ± 0.09	0.76	n. s.
MLSI	0.22 ± 0.11†	0.19 ± 0.13	0.15 ± 0.08	3.87*	P = 0.036

n. s.: non-significant level
*Represents p < 0.05 by one-way ANOVA test
† Significant differences between groups, genu varum vs. genu valgum and genu varum vs. normal knee (p < 0.05)

Table 3 Dynamic OSI (overall stability index), APSI (anterior-posterior stability index) and MLSI (medial-lateral stability index) were standardized with subject's height (stability index/subject's height in cm) and expressed as 10^{-2}, mean (SD).

Dynamic balance index	Genu varum (n = 30)	Genu valgum (n = 30)	Normal knee (n = 30)	Knee factor F-value	Tukey test P-value
OSI	1.36 ± 0.35	1.54 ± 0.69	1.39 ± 0.39	1.93	n. s.
APSI	0.97 ± 0.28	1.11 ± 0.48	1.01 ± 0.26	1.44	n. s.
MLSI	0.95 ± 0.34†	0.80 ± 0.23	0.75 ± 0.20	4.18*	P = 0.031

n. s.: non-significant level
*Represents p < 0.05 by one-way ANOVA test
† Significant differences between groups, genu varum vs. genu valgum and genu varum vs. normal knee (p < 0.05)

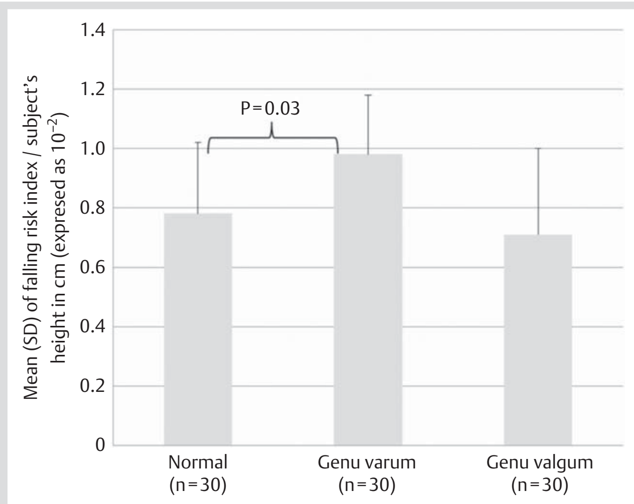

Fig. 2 Comparison of falling risk index between genu varum, genu valgum and normal groups.

function to maintain LOG in the base of support (BOS) [4]. Gatev and colleagues showed that subjects with a neutral foot structure mainly use ankle strategy to control balance and maintain the LOG in the BOS [10]. However, the change in the foot structure may alter the foot function for balance control [3]. In 2005, Cote and colleagues showed greater stability index and more postural sway in subjects with pronated foot and suggested that postural stability may be affected by foot type under both static and dynamic conditions [8]. According to these findings, it seems that genu varum deformity causes pronation position in the foot, which may alter the balance control strategy, so that the medial-lateral stability index is increased significantly.

Impaired balance and functional mobility are major risk factors for falls [13]. On the other hand, knee deformities such as genu varum may induce knee misalignment, so that it may affect the balance control function of the body [19]. However, our findings showed a significantly higher falling risk (%34.6) in subjects with genu varum deformities compared to normal subjects. Although, the recorded falling risk index value was in the normal range, it has been shown that genu varum deformity may increase the medial-lateral gravitation torque on the knee and lower limb [25]. This may easily perturb the balance control procedure especially in elderly people, who usually suffer from falls which cause a major health problem that affects their quality of life [23]. According to a search among published papers, it was found that no study had investigated the relation between falling risk and knee deformities, even in elderly people, who usually suffer from genu varum deformity and the high risk of falling. The results of the current investigation indicated a significant relation between genu varum and falling risk in young people, while these findings need to be investigated in the population of the elderly with genu varum deformities.

Conclusion

The results of this study show that genu varum deformity may increase postural sway in the medial-lateral direction and cause balance perturbation by increasing the falling risk indices. According to these findings, the subjects with genu varum deformity might be at risk of injury during sport activity due to the balance deficit. Therefore, it might be necessary to recommend a balance control training programme for those subjects interested in participating in sport activities to prevent any further injury. However, the results would be even more valuable if such a study was carried out in a larger population and also among the elderly.

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References

1 *Anker LC, Weerdesteyn V, van Nes IJ, Nienhuis B, Straatman H, Geurts AC.* The relation between postural stability and weight distribution in healthy subjects. Gait Posture 2008; 27: 471–477
2 *Aydog E, Bal A, Aydog ST, Cakci A.* Evaluation of dynamic postural balance using the Biodex Stability System in rheumatoid arthritis patients. Clin Rheumatol 2006; 25: 462–467
3 *Bal A, Aydog E, Aydog ST, Cakci A.* Foot deformities in rheumatoid arthritis and relevance of foot function index. Clin Rheumatol 2006; 25: 671–675
4 *Barrett RS, Lichtwark GA.* Effect of altering neural, muscular and tendinous factors associated with aging on balance recovery using the ankle strategy: a simulation study. J Theor Biol 2008; 254: 546–554
5 *Bernier JN, Perrin DH.* Effect of coordination training on proprioception of the functionally unstable ankle. J Orthop Sports Phys Ther 1998; 27: 264–275
6 *Bryant EC, Trew ME, Bruce AM, Kuisma RM, Smith AW.* Gender differences in balance performance at the time of retirement. Clin Biomech (Bristol, Avon) 2005; 20: 330–335
7 *Cachupe WJC, Shifflett B, Kahanov L, Wughalter EH.* Reliability of Biodex Balance System Measures. Meas Phys Educ Exerc Sci 2001; 5: 97–108
8 *Cote KP, Brunet ME, Gansneder BM, Shultz SJ.* Effects of pronated and supinated foot postures on static and dynamic postural stability. J Athl Train 2005; 40: 41–46
9 *Desai SS, Shetty GM, Song HR, Lee SH, Kim TY, Hur CY.* Effect of foot deformity on conventional mechanical axis deviation and ground mechanical axis deviation during single leg stance and two leg stance in genu varum. Knee 2007; 14: 452–457
10 *Gatev P, Thomas S, Kepple T, Hallett M.* Feedforward ankle strategy of balance during quiet stance in adults. J Physiol 1999; 514 (Pt 3): 915–928
11 *Haim A, Rozen N, Dekel S, Halperin N, Wolf A.* Control of knee coronal plane moment via modulation of center of pressure: a prospective gait analysis study. J Biomech 2008; 41: 3010–3016
12 *Harriss DJ, Atkinson G.* Update – Ethical standards in sport and exercise science research. Int J Sports Med 2011; 32: 819–821
13 *Hatch J, Gill-Body KM, Portney LG.* Determinants of balance confidence in community-dwelling elderly people. Phys Ther 2003; 83: 1072–1079
14 *Horak FB.* Clinical measurement of postural control in adults. Phys Ther 1987; 67: 1881–1885
15 *Hrysomallis C, McLaughlin P, Goodman C.* Balance and injury in elite Australian footballers. Int J Sports Med 2007; 28: 844–847
16 *Johnson F, Leitl S, Waugh W.* The distribution of load across the knee. A comparison of static and dynamic measurements. J Bone Joint Surg Br 1980; 62: 346–349
17 *Kendall FP, McCreary EK, Province PG, Rodgers MM, Romanin WA.* Muscle Testing and Function with Posture and Pain. 5th edition. Philadelphia: Lippincott Williams & Wilkins, 2005
18 *Kisner C, Colby L.* Therapeutic Exercise. 5 ed F.A Davis Company, 2007
19 *Levangie PK, Norkin CC.* Joint Structure & Function. 4 ed. F.A Davis Company, 2005
20 *Mann RA.* Biomechanics of running. In: Mann RA (ed.). Surgery of the Foot. 5 ed. St. Louis: CV Mosby, 1986; 19

21 *McGuine TA*, *Greene JJ*, *Best T*, *Leverson G*. Balance as a predictor of ankle injuries in high school basketball players. Clin J Sport Med 2000; 10: 239–244
22 *Owen JL*, *Campbell S*, *Falkner SJ*, *Bialkowski C*, *Ward AT*. Is there evidence that proprioception or balance training can prevent anterior cruciate ligament (ACL) injuries in athletes without previous ACL injury? Phys Ther 2006; 86: 1436–1440
23 *Ozcan A*, *Donat H*, *Gelecek N*, *Ozdirenc M*, *Karadibak D*. The relationship between risk factors for falling and the quality of life in older adults. BMC Public Health 2005; 5: 90
24 *Perron M*, *Hebert LJ*, *McFadyen BJ*, *Belzile S*, *Regniere M*. The ability of the Biodex Stability System to distinguish level of function in subjects with a second-degree ankle sprain. Clin Rehabil 2007; 21: 73–81
25 *Plastanga N*. Anatomy and Human Movement Structure and Function. 5th edition. Butterworth-Heinemann, 2006
26 *Sturnieks DL St*, *George R*, *Lord SR*. Balance disorders in the elderly. Neurophysiol Clin 2008; 38: 467–478
27 *Thacker SB*, *Stroup DF*, *Branche CM*, *Gilchrist J*, *Goodman RA*, *Porter Kelling E*. Prevention of knee injuries in sports. A systematic review of the literature. J Sports Med Phys Fitness 2003; 43: 165–179
28 *Tsai LC*, *Yu B*, *Mercer VS*, *Gross MT*. Comparison of different structural foot types for measures of standing postural control. J Orthop Sports Phys Ther 2006; 36: 942–953
29 *Van Gheluwe B*, *Kirby KA*, *Hagman F*. Effects of simulated genu valgum and genu varum on ground reaction forces and subtalar joint function during gait. J Am Podiatr Med Assoc 2005; 95: 531–541