Research (Annexure IIC)

Annexure II C. Research

List of completed projects at MGM CHMS (Jan 2016- Jan' 2020)

Sr. No	Title	Project	Status
1	Evaluation of balance in Indian classical dancers and age matched controls – a comparative study	MPT, MGM IHS	Completed
2	Comparison of functional performance among people with unilateral/bilateral total knee replacement and conservatively managed osteoarthritis of knee	MPT, MGM IHS	Completed
3	Effect of yoga and conventional exercises on standing balance in people with diabetic peripheral neuropathy	MPT, MGM IHS	Completed
4	Spine and Lower extremity Kinematics of Suryanamaskar	MGM IHS	Completed
5	Gait Kinematics of Indian Classical Bharatnatyam Dancers	MGM IHS	Completed
6	Evaluation of joint angles and net joint moments in rope jumping	MGM IHS	Completed
7	The effects of labor and birth positioning on pelvic dimensions: gaining further insight to improve the birth experience	Indo-Canadian Shastri Foundation, MGMIHS	Completed
8	Gait analysis using i-sens wearable system and 3D motion analysis	IIT-Madras, MGMIHS	Completed
9	Biomechanical analysis and energy expenditure of traditional, chair and wall Suryanamaskar	Sancheti College of Physiotherapy- MGM IHS	Completed
10	Comparison of erector spinae muscle activity in healthy adults and Mathadi workers with mechanical low back pain with and without spring loaded passive exoskeleton	MPT, MGM IHS	Completed
11	Influence of squatting on back muscles, pelvic motion and Labour outcomes in pregnant women	MPT, MGM IHS	Completed
12	To study the nerumusculoskeletal, cardiopulomonary , cognitive and psychological effects of "Thoppukaranam" in Healthy Adults	MPT, MGM IHS	Completed
13	Comparison of plantar cutaneous sensory thresholds in barefoot and shod adults	MPT, MGM IHS	Completed
14	Biomechanical exploration of Yoga for its scientific Application in low back pain	MGM IHS	Completed

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List of ongoing projects at MGM CHMS (2016-19)

Sr. No	Title	Project	Status
1	Effect of squatting on knee articular cartilage in healthy people	PhD , MGM IHS	Ongoing
2	Long term monitoring of functional outcome of multilevel orthopedic surgeries in children with cerebral palsy	PhD, MGM IHS	Ongoing
3	Development of a Powered Trans-tibial Prosthesis	DBT	Ongoing
4	Exploring biomechanics of Yogasana	MGM IHS	Ongoing
5	Comparison of newly developed prosthetic designs against conventional prosthesis in unilateral above knee amputation patients	IIT-M, IIT-B, MGM IHS	Ongoing
6	Biomechanical exploration of Yoga for its scientific Application in Health care	MGM IHS	Ongoing
7	Biomechanical exploration of Bharatanatyam dance postures	MGM IHS	Ongoing

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List of Publications

Sr. No	Title	Author	Journal	Year	Indexing
1	Influence of habitual deep squatting on kinematics of lower extremity, pelvis and trunk	Bela Agarwal, Robert Van Deursen, Rajani Mullerpatan	International Journal of Health and Rehabilitation Science	2018	Pubmed, Scopus, UGC
2	Birthing experience of women who have undergone normal delivery in selected community of India	Nancy Fernandes, Shobha Gaikwad, Andrea Hemmerich, Rajani Mullerpatan, Bela Agarwal	International Journal of Innovative, Knowledge Concepts	2018	Pubmed, Scopus, UGC
3	Spine and Lower extremity Kinematics of Suryanamaskar	Rajani Mullerpatan, Bela Agarwal, Triveni Shetty, Omkar SN	International Journal of Yoga	2018	Pubmed, Scopus, UGC
4	Comparison of foot structure between urban and rural Indian children	Rajani Mullerpatan, Yuvraj Singh, Blessy Ann Thomas	The Journal of Indian Association of Physiotherapists	2018	UGC
5	Influence of Varying Squat Exposure on Knee Pain and Function among People with Knee Osteoarthritis	Bela Agarwal, Manisha Advani, Robert Van Deursen, Rajani Mullerpatan	Critical Reviews™ in Physical and Rehabilitation, Medicine	2019	Pubmed, Scopus, UGC
6	Exploration of Gait Deviation Index in children with cerebral palsy with severe gait impairment	Triveni Shetty, Ashok Johari, Sailakshmi Ganesan, Rajani Mullerpatan	Critical Reviews™ in Physical and Rehabilitation, Medicine	2019	Pubmed, Scopus, UGC
7	Gait Kinematics in Bharatanatyam dancers with and without low back pain	Rajani Mullerpatan, Juhi Bharnuke, Claire Hiller	Critical Reviews™ in Physical and Rehabilitation, Medicine	2019	Pubmed, Scopus, UGC
8	Survey of Musculoskeletal Disorders among Indian dancers in Mumbai and Manglore	Shruti nair, Shruti Kotian, Rajani Mullerpatan	Journal of Dance, Medicine and Science	2018	DOAJ, EMBASE/ Index Copernicus, Index Medicus for South-East Asia Region, Indian Science Abstracts, IndMed,MedInd,, Scimago Journal Ranking, SCOPUS
9	Evaluation of Daily Walking Activity in Patients with Parkinson Disease	Akanksha Pisal, Bela Agarwal,& Rajani Mullerpatan MGM School	European Spine Journal	2019	Pubmed, Scopus
10	Lower extremity Muscle	Triveni Shetty(CA),	Critical Reviews™ in	2019	Scopus

	Strength and Endurance in ambulatory children with cerebral palsy (CRP-29963)	Shrutika Parab,Sailakhsmi Ganesan; Rajani Mullerpatan	Physical and Rehabilitation, Medicine		
11	Development of deep-squat milestone in typically developing children (CRP-29864)	Rajani Mullerpatan(CA), Meera Thanawala, Bela Agarwal, Sailakshmi Ganesan	Critical Reviews™ in Physical and Rehabilitation, Medicine	2019	Scopus
12	Review of Contextual Factors Influencing Function Following Lower Extremity Amputation in Low to Middle Income Countries	Rajani Mullerpatan, Megha Sonkhia, Blessy Thomas, Swagatika Mishra, Abhishek Gupta, Bela Agarwal	Critical Reviews™ in Physical and Rehabilitation	2019	Scopus
13	Review of lower extremity function following SEMLS in children with cerebral palsy	Rajani Mullerpatan (CA), Triveni Shetty, Sailakshmi Ganesan, Ashok Johari	Critical Reviews™ in Physical and Rehabilitation	2019	Scopus

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Original Article

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Comparison of foot structure between urban and rural Indian school children

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Abstract:

INTRODUCTION: Limited information on morphological characteristics of feet among rural (walking predominantly bare foot) and urban Indian children motivated this study. The objective was to study and compare foot characteristics of Indian rural and urban school children.

METHOD: A convenience sample of 200 healthy children aged 6-15 yrs with no history of foot pain was studied. 100 rural children were matched on marginal distributions for age and body mass with 100 urban children for comparison. Plantar pressure and foot geometry measurements were collected using EMED-SF system. Medial longitudinal arch height was recorded using Arch Index (AI). ANCOVA and Independent sample *t*-test were used for between group comparisons.

RESULTS AND CONCLUSION: Rural Indian children presented with 24 % lower body weight (BMI rural children = 15.35; BMI urban children = 18.17) and 5% lower height. When corrected for stature, they had 4% shorter feet, 3% wider forefoot, 28% narrower mid foot and 15% higher arches compared to urban children. When corrected for body weight, rural children demonstrated approximately 22% lower pressures in forefoot and 5% in the mid foot. Foot characteristics of rural children can be considered favorable in development of MLA and prevention of forefoot injuries resulting from overuse.

Keywords:

Barefoot, India, tribal

Introduction

Development of the foot continues up to 12 years of age.[1,2] It is also known that foot anthropometry varies across populations.[3] Yet, there is scarce information on morphological characteristics of the feet in various populations. A growing structure in the first decade of life which varies globally demands extensive study. In countries like India where children continue to walk bare feet predominantly in rural parts, it is particularly essential to explore foot characteristics with an intention to safeguard their foot health and consequently lower extremity function. Among the common abnormalities encountered in growing phase of life, the development of longitudinal arch has received maximum attention possibly due to deeper understanding of its implications on lower extremity function.[3-7]

The habitual use of footwear from early childhood may influence shape and probably function of the foot. Traditional Chinese foot binding is an extreme example showing that human foot is a highly plastic structure, but even daily footwear is known to influence foot.[8] Studies on Chinese and medieval British populations reported foot deformities resulting from restrictive footwear.[9,10] In the USA, 88% of healthy women surveyed walked with shoes smaller than their feet and 80% of them had some sort of foot deformity.[11] However, differences between habitual shod and unshod foot are not well understood although researchers posed this question a century ago. Hoffmann, using a limited sample size, noticed that habitual, or native, barefoot walkers universally have

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wider toe regions, a trend also observed in classical sculptures.[12]

Recently, a few studies have reported descriptive findings on foot shape and function in habitually unshod populations. Habitual barefoot adult walkers from Java had relatively long and wide feet; whereas in China, a relatively spread anterior part was reported in habitually barefoot adults.[9,13] In Congo, urban (predominantly shod) children had higher proportion of flat feet than in rural (predominantly unshod) children.[14] Similarly, in India, the incidence of flat feet was most common in children who wore closed-toe shoes, less common in those who wore sandals or slippers, and least in the unshod.[15]

However, a major limitation with these studies is the reliability of outcome measure used. Some of them have used static footprints to record foot geometry. Reliability of footprints is challenged.[3] Moreover, value of static footprints in informing foot geometry during dynamic functional activities like gait is limited. Second, only a few have studied plantar pressures among barefoot walkers which can provide robust information on foot geometry and loading during walking to indicate dynamic foot function.[16]

The present study compared foot structure between rural and urban Indian children using robust objective outcome measures during dynamic condition, i.e., walking. Findings from the present analysis also help explore whether daily footwear influences normal function of the foot and if so, does this have implications for clinicians and footwear manufacturers?

Materials and Methods

The study was approved by the Institutional Review Board of MGM Institute of Health Sciences. Table 1 provides definitions of geometric and pressure measurements. Informed consent was sought from all parents and school authorities. A convenience sample of 200 healthy children aged 6–15 years with no history of foot pain was studied. One hundred rural children from Municipal Schools of Ransai and Chikale villages located in Raigad district of Maharashtra were matched on marginal distributions for age, height, and body mass with 100 urban children from MGM School, Navi Mumbai, Maharashtra, for comparison.

Foot geometry and plantar pressure measurements were collected using EMED-SF system (Novel GmbH, Munich, Germany), which is a capacitance transducer-based system to record foot geometry and pressures of a person walking barefoot. Foot length (FL), forefoot width, mid-foot width, hindfoot width, and maximum peak pressure (MPP) over forefoot, mid-foot, and hindfoot (MPPFF, MPPMF, and MMPHF) were recorded. The platform was integrated into a wooden walkway to ensure level surface. All children were asked to walk bare feet across the platform at self-selected speed and five right and five left steps of mid-gait were recorded for analysis [Figure 1]. Average of data from five right and five left steps was used for further analysis.[17]

Arch index (AI) was recorded to study medial longitudinal arch (MLA) height because of strong correlation with radiographic measures of calcaneal inclination.[18] AI was computed as a ratio of surface area of mid-foot and total foot, excluding toe region [Figure 2] based on values provided by the EMED system. The MLA is classified as elevated (AI < 0.21), normal (0.22 < AI < 0.26), or low (AI > 0.26).[19]

ANCOVA and independent sample t-test were used for between-group comparisons.

Results

Average height, body weight, and body mass index varied significantly between two groups [Table 2]. Rural children presented mean shorter FL compared to urban

Figure 1: Use of EMED platform for measuring foot structure and pressures

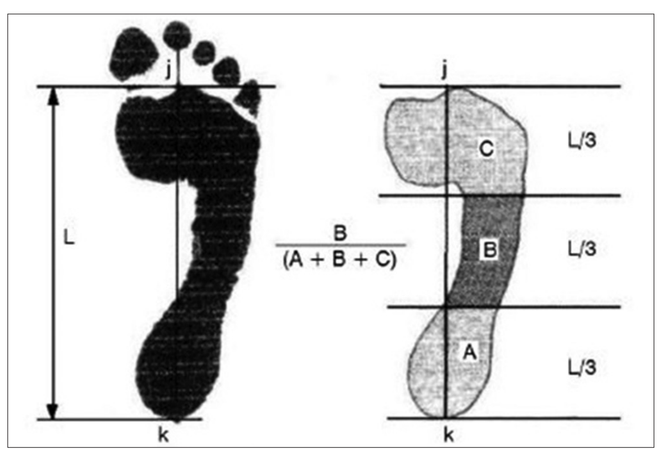

Figure 2: Calculation of arch index

Table 1: Definitions of geometric and pressure measurements

Measurement	Definition
Foot length	Defined by placing a rectangle around the maximum pressure picture whose long side is parallel to the bisection of the long plantar angle. The length of the rectangle defines the foot length.
Fore foot width	Distance between the widest points of the ball of the foot (1st and 5th metatarsophalangeal joints)
Hind foot width	Heel width distance between the widest points across the flash portion of the heel
Mid foot width	Distance between the near most points across the flash portion of mid foot
Arch Index	The index is defined by the mid foot area divided by the total foot area (foot area minus toes area)
Maximum Peak Pressure (MPP)	Defined as maximum pressure detected by any single sensor in each mask measured in a single step
Gait line velocity	Average instantaneous force over the planar foot as a function of time.

Table 2: Comparison of age, height, weight and body mass index between rural and urban children

	Rural	Urban	*p*
Age (years)	9.95 (2.91)	10.99 (3.09)	0.95
Height (cm)	129.04 (14.43)	134.42 (19.06)	0.01*
Weight (kg)	25.54 (06.47)	33.73 (11.71)	0.00*
Body Mass Index (BMI)	15.35 (01.59)	19.17 (2.91)	0.00*

*Results expressed as mean (SD); *p<0.05=significant*

Table 3: Comparison of foot geometry between rural and urban children

	Rural	Urban	P
Foot Length (Rt)	20.61 (1.91)	22.33 (2.67)	0.00*
Foot Length (Lt) (mm)	20.64 (1.93)	22.34 (2.61)	0.00*
Fore Foot Width (Rt) (mm)	9.57 (0.79)	9.99 (1.02)	0.00*
Fore Foot Width (Lt) (mm)	9.67 (0.97)	9.91 (0.99)	0.00*
Mid Foot Width (Rt) (mm)	1.79 (1.20)	2.62 (1.41)	0.00*
Mid Foot Width (Lt) (mm)	1.56 (1.16)	2.41 (1.29)	0.00*
Hind Foot Width (Rt) (mm)	5.34 (0.57)	5.70 (0.74)	0.00*
Hind Foot Width (Lt) (mm)	5.24 (0.61)	5.53 (0.66)	0.00*
%Foot length/stature (R)	16.14 (0.91)	16.67 (1.07)	0.00*
%Foot length/stature (L)	16.19 (1.06)	16.69 (1.01)	0.00*
% Forefoot width/foot length (R)	41.72 (3.32)	40.49 (4.34)	0.02*
% Forefoot width/foot length (L)	42.06 (3.76)	39.79 (5.76)	0.00*
% Midfoot width/foot length (R)	9.44 (5.44)	11.66 (6.09)	0.00*
% Midfoot width/foot length (L)	7.59 (5.44)	10.75 (5.53)	0.00*
% Hindfoot width/foot length (R)	26.03 (2.93)	25.70 (3.33)	0.44
% Hindfoot width/foot length (L)	25.49 (3.00)	24.92 (3.11)	0.19
Arch Index (Rt)	0.20 (0.06)	0.23 (0.06)	0.00*
Arch Index (Lt)	0.19 (0.05)	0.22 (0.05)	0.00*

*Results expressed as mean (SD); *p<0.05=significant*

children [Table 2]. Expressed as a percentage of total body stature, rural children had 4% significantly shorter feet. Comparison of foot width as a percentage of FL (a measure for overall foot shape), significant differences between two groups emerged. Rural children presented with 3% wider forefoot and 29% narrower mid-foot.

(AI) based on areas of MPPFF, MPPMF, and MMPHF using the EMED-SF system. Rural children presented with 15% higher arch compared to the urban counterparts [Table 3].

Differences in pressure distribution were most prominent on the heel and in metatarsal region despite similar gait line speeds. Rural children demonstrated approximately 22% lower peak pressures over entire foot with forefoot showing maximum difference. Twenty-two percent lower pressures were recorded in the forefoot region, approximately 5% in the mid-foot, and 17% in the hind foot; the differences in forefoot and mid-foot regions being statistically significant [Table 4].

Discussion

Literature describing unshod foot is scarce. Findings from the present study supplement existing knowledge on pediatric foot structure. Rural Indian children presented with approximately 4% shorter feet with 3% wider forefoot, 28% narrower mid-foot, and 15% higher MLA compared to urban children. Interesting observations (similarities and variations) emerge from comparison of our findings with findings reported from other Asian populations.

Slightly shorter feet of rural children may be because rural children were 5% shorter in total body height compared to urban children. It is already known that people with shorter body height tend to have shorter feet.[20] Rural children may be shorter compared to their age-matched urban counterparts because it is likely that rural children consume less nutritious food and it is known that body nutrition is directly associated with body height.[21] In the absence of published studies comparing FL of rural versus urban children, it is not possible to comment on FL of rural children from other populations. However, it is interesting to discuss FL of adult rural and urban barefoot walkers (intentionally chose to walk barefoot) from India. Adult rural barefoot walkers presented with shorter body stature and shorter foot compared to urban barefoot walkers, which is similar to the present findings from children. However, rural adult barefoot walkers presented with longer foot after correcting to body stature, which leaves with speculation that rural children demonstrate a sudden sharp gain in body height at puberty w.r.t. FL, and therefore, in adulthood, rural people present with longer feet compared to urban children.[13,16]

Wider forefoot of the rural children can be explained with greater prehensile activity of forefoot required to adapt to uneven terrain during push-off while walking barefoot for a large part of the day for indoor and outdoor activities which is noted even in adult rural Indian barefoot walkers.[16]

Table 4: Comparison of plantar pressures between rural and urban children

Maximum Peak Pressure (kPa)	Rural	Urban	*p*
Fore foot (Rt)	167.90 (49.10)	204.00 (95.39)	0.04*
Fore foot (Lt)	169.00 (56.16)	199.60 (59.14)	0.00*
Mid foot (Rt)	92.95 (29.61)	96.95 (32.50)	0.00*
Mid foot (Lt)	92.90 (29.93)	99.20 (30.62)	0.01*
Hind foot (Rt)	195.30 (57.92)	217.10 (79.64)	0.54
Hind foot (Lt)	199.15 (63.99)	215.70 (57.33)	0.59
Total (Rt)	224.45 (56.03)	299.15 (103.53)	0.39
Total (Lt)	231.90 (64.66)	270.60 (93.19)	0.12
Gait line velocity (R) m/s	0.29 (0.03)	0.29 (0.04)	0.49
Gait line velocity (L) m/s	0.29 (0.03)	0.29 (0.04)	0.31

*Results expressed as mean (SD); *p<0.05=significant by ANCOVA (contact time in respective areas is used as a covariate)*

Narrow mid-foot in the rural children is consistent with higher MLA compared to urban children. Rural children presented with 15% higher MLA as compared to urban children. Rural children walked bare feet daily on uneven terrain for 2–4 h approximately while accompanying their parents on fields and walking and playing around house. Children walked on uneven terrain for approximately 4–8 km daily to and from school in footwear in the form of open slippers provided by school, which were mostly worn out. However, urban children walked shod for all outdoor activities. They traveled to school in buses or cars and generally walked lesser compared to their rural counterparts. It is known that walking bare feet challenges the use of intrinsic muscles which facilitates the development of MLA, resulting in higher prevalence of flat feet among children using footwear compared children walking bare feet.[15] These findings are similar to those reported in Brazilian and Central African schoolchildren, with the low prevalence of low feet among those walking predominantly bare feet.[3,14]

Peak plantar pressure was lower over forefoot and mid-foot in habitually barefoot rural children than in urban shod peers, despite adjusting for body weight and both groups walking at similar gait velocity. Lower pressure over wider forefoot of rural children may be due to redistribution of pressure over larger contact surface area of forefoot.[22] However, lower mid-foot pressure in the rural children may result from lesser contact surface area owing to narrower mid-foot caused by higher medial arch.

To summarize, habitual use of footwear influences both overall shape of foot and peak plantar-pressure. Habitual barefoot walkers have wider forefoot, resulting (probably along with dynamic adaptations) in lower peak pressure, favorable in the prevention of forefoot injury in sports activities as forefoot injuries are common.[23] Second higher medial arch of the foot is known to enhance athletic performance in children.[24]

The present study was a one-time study with no periodic re-assessments. Further longitudinal studies are necessary to comment on clinical implications of foot characteristics of rural children on lower limb function. Second, it lacks exploration of influence of nutrition-related factors (body height and mass) and life style-related factors (barefoot walking) on developing feet.

Conclusion

Rural Indian children presented with 24% lower body weight and 5% lower height. When corrected for stature, they had 4% shorter feet, 3% wider forefoot, 29% narrower mid-foot, and 15% higher arches compared to urban children. When corrected for body weight, rural children demonstrated approximately 22% lower pressures in the forefoot and 5% in the mid-foot. Foot characteristics of rural children can be considered favorable in the development of MLA and prevention of forefoot injuries resulting from overuse.

Acknowledgment

We express their gratitude for all children for their voluntary participation. Furthermore, we wish to acknowledge their parents and the school teachers for helping us in data collection.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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Influence of habitual deep squatting on kinematics of lower extremity, pelvis and trunk

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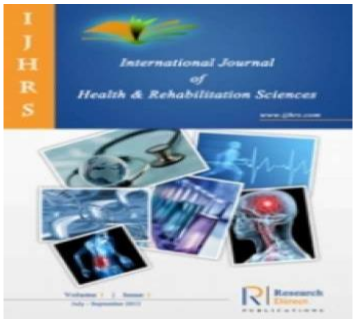

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Influence of habitual deep squatting on kinematics of lower extremity, pelvis and trunk

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ABSTRACT

Background: Deep squatting is traditionally adopted for self-care, activities of daily living (ADL), leisure and occupation in India and other parts of the world. However western life style is gradually replacing squatting with sitting postures. Given the fact that there is now huge variation in the use of deep squatting in people's daily lives in India.

Purpose: The aim of this study is to explore differences in adaptations in lower limb kinematics among people with varying levels of exposure to deep squatting.

Method and Materials: Kinematic analysis of deep squat was performed in 8 adults 30-45yr of age who don't squat daily(non-squatters), 10 adults who squat on a daily basis(ADL-squatters) and 8 adults who use squatting very regularly for long durations of time (occupational-squatters). Five trials of deep squat were captured using. Vicon Nexus software at 100 Hz. Full body plug-in-gait model was used with 4 additional markers on left-right iliac crests and medial femoral-condyle to allow for reconstruction of marker trajectories lost during parts of the movement

Results: BMI was used as a covariate to account for differences in the lifestyle characteristics. There were significant differences between groups in maximum knee flexion (p<0.05). Occupational-squatters had greatest knee flexion followed by ADL-squatters and least knee flexion was seen in non-squatters'.

Conclusion: Longer squat exposure appears to influence maximum knee flexion during deep squat which may be indicative of soft tissue adaptation at the knee. Reduction in joint range of motion if not used during habitual activities indicates specific adaptation of the body to the daily stresses it is exposed to.
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Key Words: biomechanics; motion analysis; deep squatting

INTRODUCTION

Deep squatting, is an exercise activity that uses the persons own body weight and gravity to strengthen muscles, train balance, exert load bearing stimulus and evoke full flexion at hip, knee and ankle joints[1,2,3]. In many parts of the globe particularly in south-east Asian and African countries, deep squatting is habitually adopted for self-care activities, activities of daily living (ADL), occupational and leisure tasks[4,5,6]. It has been proposed that there is a potentially protective effect of deep squat against development of knee arthritis in Asians and Indians who adopt these postures as a part of their cultural practices[7].

However, modernization of life style across the world has influenced Asian and African continents resulting in reduction in traditional ground level activities in these countries. In India, there is now a large variation in the use of squatting; on the one hand people have given up squatting completely while on other hand people spend long hours squatting for activities of daily living and occupational activities[7]. However, between the two ends of the spectrum lies a large portion of population that squats for moderate duration to perform self-care activities like toileting and household chores.

Although, abundant literature is available on kinematics and kinetics of partial squat[8, 9, 10, 11] deep squat has been studied predominantly as a sport activity and as a posture adopted while performing occupational activities. While partial squat and deep squat have been attributed to offer beneficial effects to musculoskeletal structures around the knee[1,9-14], squatting for prolonged duration of time has also been propounded as a risk factor predisposing towards osteoarthritis (OA) of knee[15-19]. Currently, there is no consensus on how varying squatting exposure affects the knee joint. Literature search reveals that knee kinematics during squat are affected by increasing age[20,21]. They are reported to vary between male/female genders[22,23] and with varus/valgus foot position and depth of squat[24]. However, the effect of varying duration of squatting exposure on joint kinematics remain unexplored.

Currently lifestyle modification for people with knee dysfunction includes recommendation to forgo high flexion activities like squatting[25-28] although these activities are an integral component of ADL[7]. Therefore understanding the kinematic demands of ankle, knee, hip and trunk in people with varying squat exposure is justified.

Hence the current study was undertaken to explore the hypothesis that high daily exposure to deep squatting influences kinematics of lower extremity, spine, and trunk.

Method and Materials

Subjects characteristics and general experimental design

Study subjects

Ethical approval was sought from Ethical Committee for Research on Human Subjects, MGM Institute of Health Sciences. A consecutive consenting sample of 28 healthy adults (30-50 years) was recruited for the study following informed consent as per Declaration of Helsinki guidelines. Participants were screened for presence of musculoskeletal conditions like back pain, pain in joints of lower extremity due to degenerative or autoimmune disorders, bony or soft tissue injury, previous surgery, developmental disorders, neurological conditions, cardiopulmonary conditions and cognitive issues prior to recruitment. Participants were grouped on the basis of daily squat exposure. People who did not have any daily squatting exposure in the past year were grouped as non-squatters. People who adopted deep squat for self-care and ADL like washing clothes, cooking, mopping, sweeping and leisure activities were grouped as ADL squatters while occupational squatter group included people who adopted deep squat daily when performing occupational activity (laborers, house maids and gardeners).

Daily Squat exposure was quantified using a validated MGM Ground Level Activity Exposure Questionnaire-interview based (MGMGLAE; Cronbach alpha for reliability 0.89). Squatting exposure was categorized into self-care, instrumental activities of daily living and occupational, sport and leisure activities. Self-care was further sub divided into squatting for toileting, bathing and eating, instrumental activities of daily living (IADL) category was sub divided into washing clothes, cleaning utensils, sweeping, mopping, and cooking. Self-reported time spent in squat on a daily basis for the above activities was recorded. Exposure duration to squatting for occupation, sport and leisure activities was also noted. Daily exposure in each category was summated to quantify total daily squat exposure (Refer Table 1, 2).

Demographic details such as age, height, weight, body mass index (BMI) were noted. Participants were scored on modified Kuppuswamy Socioeconomic Status Scale applicable to the Mumbai population which ranked and classified them on an ordinal scale into upper, middle–upper, middle, lower-upper and lower class on the basis of monthly family income, educational qualification and occupation[29].

3D movement analysis of deep squat was performed at MGM Center of Human Movement Science. Anthropometric data such as shoulder offset, elbow, wrist, hand, knee and ankle width, and inter anterior superior iliac spine (ASIS) distance, leg length were recorded and used for inverse dynamic calculations. Forty two retro reflective spherical markers were applied to anatomical landmarks using plug-in-gait full body marker set with four additional markers at right-left/bilateral iliac crest and medial femoral condyles in order to aid reconstruction of body segments[30]. Data were captured at 100 Hz using a 12 camera Vicon motion capture system (Oxford Metrics Ltd, UK). Ground reaction force data were collected using 2 AMTI force plates (Advanced Mechanical Technology Inc, USA). A static anatomical calibration trial was captured and was used to align joint axis. This was followed by six dynamic deep squat trials. Data were filtered with a Butterworth filter at a cut off frequency of 6 Hz for marker trajectories and 10Hz for analog data.

Participants were instructed to descend into deep squat keeping hands forward throughout the trial to prevent loss of markers. Deep squat was sustained for 10 seconds followed by ascend to standing position. No instruction regarding foot placement was provided except to place one foot on each force plate in an attempt to obtain a natural squat performance.

The trials were processed within Vicon Nexus 2.5. Gaps in marker trajectories were filled using standard gap filling techniques. ASIS marker trajectory interrupted during deep squat was filled using the rigid body technique in Vicon Nexus with use of the additional iliac crest markers. Outcome variables computed were joint angles at hip, knee, ankle, pelvic tilt and thorax inclination. All joint positions were reported at peak knee flexion.

Statistical Analysis

Data were analyzed using SPSS version 24(SPSS IBM, New York, USA). Normality of distribution was ascertained, measures of central tendency and dispersion were calculated and reported as means and standard deviation. Comparison for symmetry of motion between sides was performed using paired t test. Comparison among groups for squat exposure and joint angles was performed using a one way ANCOVA with BMI as covariate and post-hoc contrasts using Bonferroni adjustment. Level of significance was considered at $p<0.05$ for the ANOVA and $p<0.025$ for the contrasts. Associations between joint angles, BMI and Kuppuswamy score were analyzed using Pearson’s /Spearman’s correlation coefficient as appropriate.

RESULTS

Demographic characteristics, daily deep squat exposure and joint angles of non-squatters, ADL squatters and occupational squatters are presented in Table 1,2&3, Figure1-3.

Body mass index was significantly different among the three groups (P =.024) with occupational squatters having lowest BMI 20.3

(4.4) $kg.m^{-2}$ and non-squatters having the highest 25.9 (3.1) $kg.m^{-2}$. Among non-squatters, 50% people were overweight and 50% were obese. 70% of ADL squatters had a BMI within normal range, 20% were overweight and 10% were obese. Occupational squatters had the least BMI with 37% of people having below normal BMI, 50% having normal category and 13% were obese.

Total daily squatting exposure was nil in non-squatters while ADL squatters had a total daily squatting exposure of 41.0 (22.5) min/day spent for self care and IADL living like washing clothes, sweeping, mopping, cooking and other household chores. Occupational squatters had a total daily squat exposure of 229.37 (67.1) min/day. These differences were found to be statistically significant ($P < .001$). The high cumulative score in occupational squatters was divided between 147.5 (54.4) min/day in deep squat for occupational activity and 81.8 (19.9) min/day for self-care, IADL and leisure activity.

All occupational squatters were categorized as upper-lower socioeconomic class, 60% ADL squatters were people from upper class and 40% were from upper middle class. All non-squatters were categorized as upper class as defined by the Kuppuswamy Socioeconomic Status Scale.

Deep squat symmetry was analyzed by comparing left and right joint angles. With the exception of asymmetry in hip rotation in non-squatters ($Right_{Hip\ Internal\ Rotation}$ 19.2 (13.7^0) and $Left_{Hip\ Internal\ Rotation}$ 46.5 (20.6^0), Left >Right by 142 %), hip, knee and ankle joint angles were symmetrical on both sides in occupational squatters, ADL squatters and non-squatters. Hence, only data from right ankle, knee, and hip joint were considered for further analysis.

Ankle dorsiflexion motion during deep squat was largest in ADL squatters 45.2 (6.2^0), followed by occupational squatters 41.7 (7.7^0) and least in non-squatters 31.6 (30.5^0). However the difference was not statistically significant ($P = .277$). It was also observed that 40% of non-squatters could not perform a foot flat deep squat and a high standard deviation was seen in ankle dorsiflexion angle (Refer Table3, Figure1).

With respect to knee sagittal plane motion, a statistically significant difference was observed in maximum knee flexion during deep squat among the three groups even after adjusting BMI as a covariate ($P < .05$). Occupational squatters had the greatest knee flexion angle 164.6 (4.5^0) followed by ADL squatters 158.1 (4.7^0) and lowest knee flexion was seen in non-squatters 155 (7.3^0).With respect to coupled motion, knee

Table 1: Demographic characteristics of non-squatters, ADL squatters and occupational squatters

Variable	Non Squatters n=8 mean(SD)	ADL Squatters n=10 mean(SD)	Occupational Squatters n=8 mean(SD)	*P*-value
Age yrs	35.6 (4.6)	34.2 (4.1)	39.8 (5.7)	.057
Height m	1.58 (0.11)	1.62 (0.12)	1.54 (0.10)	.331
Mass kg	64.8 (7.7)	57.9 (16.9)	49.0 (13.9)	.086
BMI kg/m^2	25.9 (3.1)	21.7 (4.2)	20.3 (4.4)	.024*
Total Squat exposure min	0.0	41.0 (22.5)	229.3 (67.1)	<.001*
Kuppuswamy Scale Score	29.1 (9.5)	20.4 (12.5)	7.25 (1.0)	<.001*

Table 2: Daily squat exposure of non-squatters, ADL squatters and occupational squatters

Squat exposure categories	Non Squatters min/day mean(SD)	ADL Squatters min/day mean(SD)	Occupational Squatters min/day mean(SD)	p value using one way ANOVA
Self care	0	12.5 (3.5)	14.3 (7.2)	<.001
Instrumental Activities of Daily Living	0	21.0 (14.4)	28.7 (13.5)	<.001
Occupation	0	0	147.5 (54.4)	<.001
Leisure	0	7.5 (12.7)	38.7 (13.5)	<.001
Total squat exposure	0	41.0 (22.58)	229.3 (67.1)	<.001

* Level of significance at $p \leq 0.05$

Table 3: Kinematics during deep squat in non-squatters, ADL squatters and occupational squatters at peak knee flexion

Variable	Non Squatters n=8 mean(SD)	ADL Squatters n=10 mean(SD)	Occupational Squatters n=8 mean(SD)	*P*-value
Thorax ^{0}	29.1 (19.6)	22.4 (8.4)	22.7 (5.5)	.485
Ant Pelvic tilt ^{0}	4.9 (26.0)	-9.3 (21.7)	-12.4 (18.5)	.266
Hip Flexion ^{0}	111.0 (13.0)	106.3 (19.5)	108.7 (18.7)	.856
Hip Abd^{0}	13.2 (4.6)	13.9 (8.6)	16.7 (9.1)	.707
Hip IR ^{0} R L	19.2 (13.7) 46.5 (20.6)	18.1 (16.7) 33.7 (11.3)	31.9 (24.5) 30.4 (19.0)	NS .017* ADLS .092 OS .779
Knee Flexion^{0}	155.0 (7.3))	158.1 (4.7)	164.6 (4.5)	.008*
Knee Adduction^{0}	12.6 (16.3)	1.5 (10.9)	4.6 (10.2)	.190
Knee Internal Rotation^{0}	35.5 (15.5)	33.6 (18.5)	37.8 (19.0)	.887
Ankle Dorsiflexion^{0}	31.6 (30.5)	45.2 (6.2)	41.7 (7.7)	.227

* Level of significance at $p \leq 0.05$

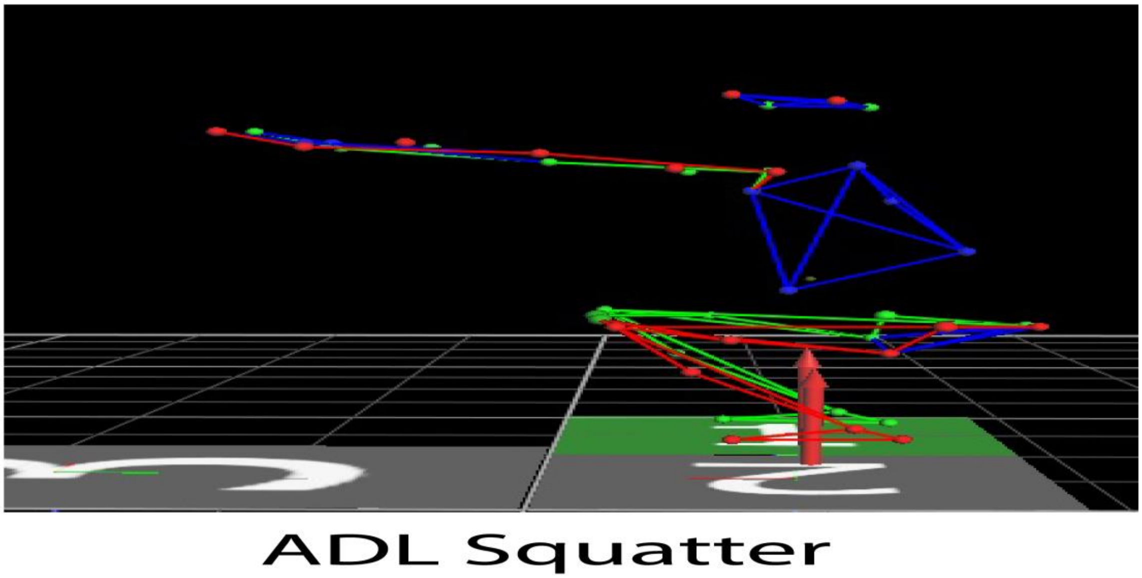
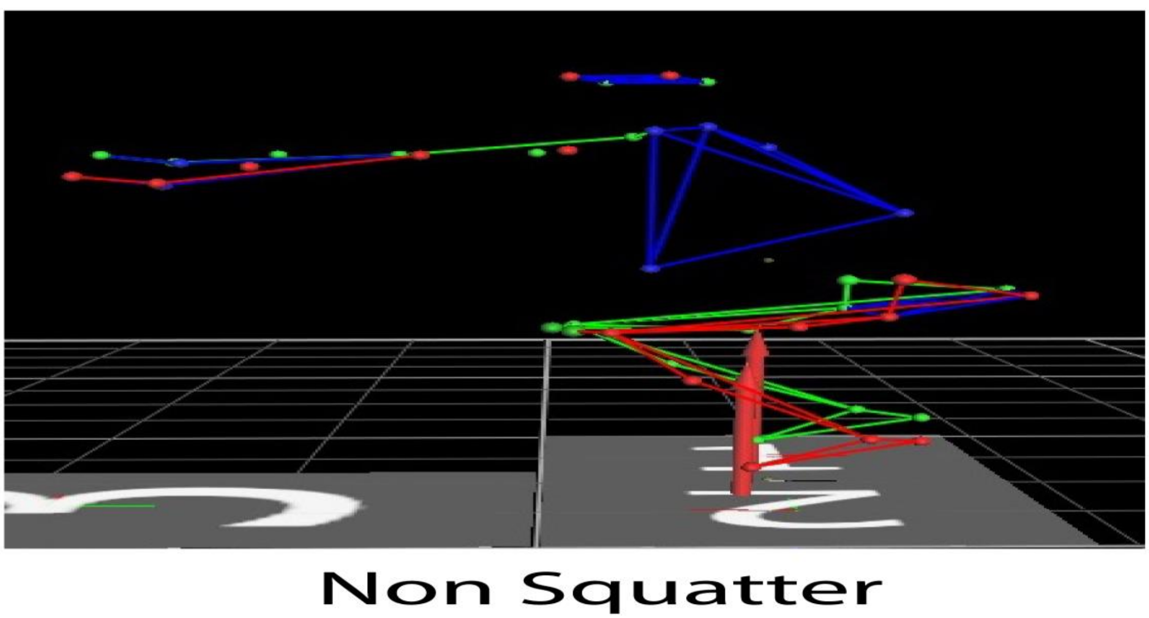
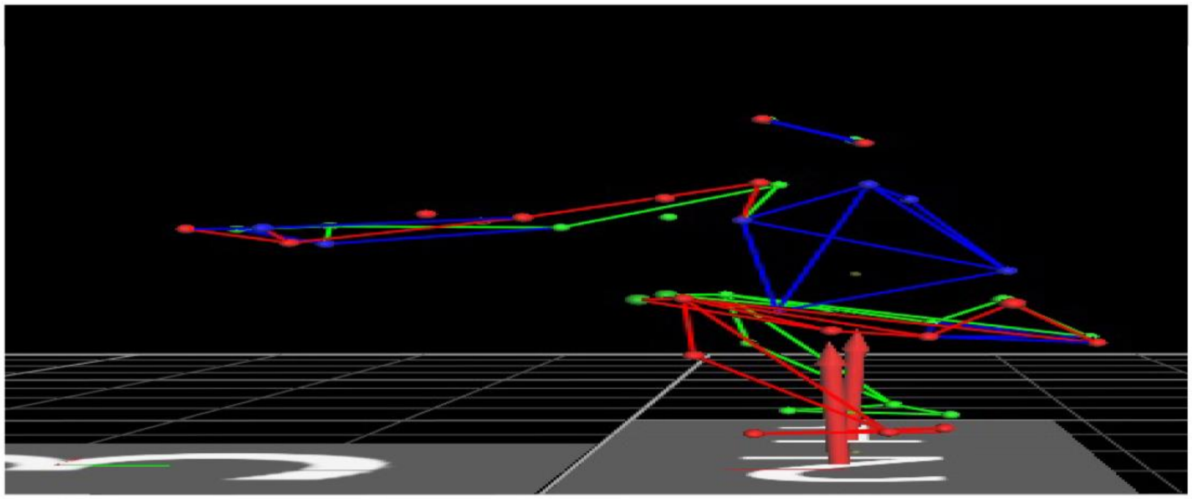


Figure 1: Deep squat position adopted by non-squatters, ADL squatters and occupational squatters





Occupational Squatter

Discussion

The objective of the study was to explore the influence of varying duration of daily squatting exposure on kinematics of the lower extremity, spine and pelvis during deep squat. It was observed that daily squat exposure had a significant influence on knee kinematics. Longer squatting exposure led to increased maximum knee flexion during deep squat. Various factors associated with squatting exposure likely to influence joint motion are discussed below.

Firstly, joint motion could likely have been influenced by BMI. Leaner people could have demonstrated higher joint angles due to lower girth of thigh and calf. Therefore BMI was used as a covariate to study its influence on joint angles. However, difference in knee joint angles amongst the groups remained significant even after BMI was adjusted as a covariate and therefore the difference is not fully explained by this factor. This suggests that inherent changes in soft tissues of knee joint occur with daily squat exposure. Soft tissues of knee like menisci, cartilage, ligaments, anterior knee capsule and bones are believed to be amenable to anabolic metabolic processes and possess an ability to adapt to increased activity and mechanical influences. This could render a protective influence on the joints structures[31]. It could be possible that as occupational squatters and ADL squatters squatted for a prolonged time their tissues adapted to these stresses and contributed to the greater flexion observed at the knee joint. High correlations between knee flexion angle and total squat exposure are consistent with this interpretation. Furthermore, increased thigh-calf contact area may lead to greater distribution of compressive force, thus providing a protective effect on the knee joint.

Secondly, influence of socioeconomic status on knee kinematics was explored with the objective of understanding lifestyle activity patterns adopted by people for daily living. All occupational squatters were from upper-lower socioeconomic class, 60% of ADL squatters were from upper class and 40% from upper middle class whereas all non-squatters were people from upper class with higher monthly family incomes and better education. Non squatters demonstrated high BMI which correlated negatively with time spent in squat for ADL, leisure activities and total squat exposure thus establishing a link between economic progression, adoption of modernized lifestyle, reduction in time spent in habitual ground level activities using squatting and joint motion.

Thirdly, total daily deep squat exposure time was highest in occupational squatters who spent 147.5 (54.4) min/day in deep squat for occupational activity in addition to 81.8 (19.9) min/day for self-care, IADL and leisure activity which leads to a high cumulative score of 229.3 (67.1) min/day. In India, people from low socioeconomic class continue to adopt squat not only for occupational activities but also for IADL which increases the habitual, repetitive loading experienced by soft tissues of and around the knee and lead to greater adaptations as seen by the greatest knee flexion angle in this group during deep squat. ADL squatters had a moderate deep squatting exposure of 41 (22.5) min/day spent in squatting predominantly for self-care and IADL thus providing the habitual, repetitive loading in moderation sufficient to bring about soft tissue adaptation at the knee. Since BMI was not influenced by socioeconomic status and differences in joint angles remained significant in spite of adjusting for BMI, it would seem reasonable to assume that difference in knee joint kinematics can be attributed to soft tissue adaptations to the habitual, repetitive loading of daily squat exposure.

Fourthly, knee motion in the sagittal plane during deep squat, increased from non-squatters to occupational squatters. Higher values of knee flexion recorded in occupational squatters 163 (4.5^0) were greater than values reported previously in Indians[25] [153.7 (10.4^0)] which may be attributed to the grouping of participants on the basis of daily squat exposure or methodological differences of using electromagnetic tracking systems versus the Vicon system. Knee flexion coupled with internal rotation has been reported earlier [20, 24,25,32,33]. Interestingly, in the current study a greater percentage of non-squatters used knee-flexion-internal rotation-adduction coupling as compared to ADL squatters or occupational squatters. Although no relationship could be established among knee motions in the three planes, this does demonstrate that different knee movement patterns existed within the group studied. Studies using 4D fluoroscopic modeling in conjunction with CT scans demonstrated a strong coupling of posterior translation of femoral condyle along with internal rotation of tibia is reported during deep flexion activity of kneeling[34]. However, it has also been described that longitudinal rotation of the knee may be influenced to a great extent by passive soft tissue structures and dynamic forces rather than bony anatomy thus changing the axis of rotation for each activity[35]. Therefore in our study of squatting as a deep flexion activity, variation in the superincumbent weight, greater degree of knee flexion, rotation and adduction during squatting appear to affect forces and movement at the joint[36,37]. It may be interesting to study in future whether greater knee flexion coupled with internal rotation-adduction along with a high BMI contributes to higher compressive forces encountered by medial compartment of knee as high correlation was observed between BMI and knee adduction.

With respect to ankle motion, although differences in sagittal plane motion were not significant, it was observed that 40% of non-squatters were unable to perform foot flat deep squat which may indicate that lack of habitual repetitive loading on soft tissues like gastrocnemius and soleus could lead to shortening of these structures which restricts the ability of tibia to move over the talus during deep squat. Similar findings are reported previously in western populations who do not adopt deep squat routinely[8]. Reduction in joint range of motion if not used during habitual activities further demonstrates specific adaptations of the body to daily stresses exemplifying the principle of ‘use it or lose it”.

Hip motion in the sagittal and frontal plane during deep squat was similar in the three groups. However greater asymmetry between right and left sides in transverse plane motion in non-squatters may be a compensatory mechanism for lack of plantar flexor muscle length and knee flexion required to maintain deep squat effectively. Occupational squatters demonstrated highest symmetry between sides and low standard deviations indicating that habitual squatting may lead to greater stretching ability of musculo-tendinous structures of knee and ankle. Additionally, habitual squatting for prolonged time durations may contribute to increased ability to sustain squat with lesser trunk flexion and posterior pelvic tilt. Although this was not significant, our data suggests that non-squatters appear to tilt their trunk further forwards to maintain their center of mass within the base of support. However, a study using a larger sample will be required to confirm this. Results from other studies suggested that restriction of forward knee displacement during squat results in changes in knee-hip coordination[36] with increase in internal angle between knee and ankle, greater forward lean at the thorax and excessive transfer of force from hips to low back thereby contributing to musculoskeletal dysfunction[31,37,38].

With respect to study limitations, a prime concern in generating inferences from motion analysis is skin artifact consisting of movement of skin markers relative to underlying bone position. Thigh segment movement artifact in transverse and frontal plane motion create kinematic noise due to shifting of markers, muscle movement and inertial impact. Current techniques are unable to nullify the effect of skin movement artifact thus the reported frontal and transverse plane motion analysis should be interpreted with caution[39-42].In addition , studies on a larger number of individuals with varying squat exposure would make it easier to confirm that differences are significant.

Conclusions

In conclusion, varying durations of deep squat exposure influences knee kinematics. Lack of deep squat exposure led to reduction in maximum knee flexion angle which increased correspondingly with squat exposure. Moderate daily squat exposure of 20-45 minutes was sufficient to demonstrate improvement in knee range of motion thereby indicating that incorporation of deep squat in activities of daily living or as an exercise may help promote or maintain mobility at the knee.

Additionally, kinematic findings from this study may help in the design of better indigenous tailor made artificial joints, prostheses and orthoses that can mimic demands of traditional lifestyle activities of Indian and Asian culture and increase acceptance of knee replacement surgeries.

Authorship and Acknowledgement

All authors have contributed substantially towards conception of design, data acquisition, data analysis, interpretation and manuscript content. Bela Agarwal contributed to data acquisition, analysis, interpretation and manuscript content, Dr Rajani Mullerpatan and Dr Robert van Deursen provided consultation and guidance for data interpretation and manuscript content. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Dr Rajani Mullerpatan will be responsible as the guarantor for the work as a whole.

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Conflict of interest: None

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Birthing experience of women who have undergone normal deliver in a selected community of India.

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Keywords: Birthing, Birthing experience of women, normal deliver

Abstract

A study was conducted on â€œBirthing experience of women who have undergone normal deliver in a selected community of Indiaâ€. The purpose of the study was to provide support & comfortable position to women during birthing process. A qualitative research approach was used to analyze the interview & content analysis was done. The finding of the study reviled that work experience of ANM (Auxiliary Nurse Midwifes) & ASHA workers, was important because with increase in number of cases they felt skillful & confident. In terms of facilities for delivery it was identified that there was no special arrangement of rooms available, they had to conduct delivery single handedly, and the position for delivery commonly used was the traditional position supine position with legs flexed & drawn towards the abdomen. The findings related to the mother evolved over their experience because all the mothers wanted a pleasant experience of delivery. The study concluded that squatting position which is adopted in daily activities of life among Indians which increased the pelvic dimension is not used during child birth.

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Kinematics of Suryanamaskar Using Three-Dimensional Motion Capture

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Abstract

Background:

Suryanamaskar, a composite yogasana consisting of a sequence of 12-consecutive poses, producing a balance between flexion and extension is known to have positive health benefits for obesity and physical fitness management, upper limb muscle endurance, and body flexibility. However, limited information is available on biomechanical demands of Suryanamaskar, i.e., kinematic and kinetic.

Aims:

The present study aimed to explore the kinematics of spine, upper, and lower extremity during Suryanamaskar to enhance greater understanding of Suryanamaskar required for safe and precise prescription in the management of musculoskeletal disorders.

Methods:

Three-dimensional motion capture of Suryanamaskar was performed on 10 healthy trained yoga practitioners with 12-camera Vicon System (Oxford Metrics Group, UK) at a sampling frequency of 100 Hz using 39 retro-reflective markers. Data were processed using plug-in-gait model. Analog data were filtered at 10Hz. Joint angles of the spine, upper, and lower extremities during 12-subsequent poses were computed within Vicon Nexus.

Results:

Joint motion was largely symmetrical in all poses except pose 4 and 9. The spine moved through a range of 58° flexion to 44° extension. In the lower quadrant, hip moved from 134° flexion to 15° extension, knee flexed to a maximum of 140°, and 3° hyperextension. Ankle moved in a closed kinematic chain through 40° dorsiflexion to 10° plantarflexion. In the upper quadrant, maximum neck extension was76°, shoulder moved through the overhead extension of 183°–56° flexion, elbow through 22°–116° flexion, and wrist from 85° to 3° wrist extension.

Conclusions:

Alternating wide range of transition between flexion and extension during Suryanamaskar holds potential to increase the mobility of almost all body joints, with stretch on anterior and posterior soft tissues and challenge postural balance mechanisms through a varying base of support.

Keywords: *Kinematics*, *lower extremity*, *spine*, *Suryanamaskar*

Introduction

Suryanamaskar referred as "sun salutation" is one of the ancient forms of Yogasanas practiced. It is a sequence of 12-consecutive poses, producing a balance between flexion and extension, performed with synchronized breathing.[1] Performing asanas in continuous sequencing, such as sun salutation and performing asanas individually, may confer different benefits to the body. However, Suryanamaskar definitely helps in better calorie burn. Extensive information is available on physiological effects of Hatha Yoga and biomechanical demands of standing Hatha Yogasanas. Combination of series of Yogasanas performed with breathing control and mindfulness have demonstrated reduction in diastolic blood pressure, improved cardiorespiratory fitness, myocardial perfusion, serum cholesterol, upper limb muscle endurance, body flexibility, balance, bone density, and overall positive benefits for weight and physical fitness management.[1,2,3,4,5,6,7,8,9] However, the effect of individual asanas remains unexplored.

Physiological demands of Suryanamaskar too are reported previously.[1,3,10] Improvements in pulmonary function, such as maximal inspiratory and expiratory pressures, forced expiratory volume in 1st s (FEV1), forced vital capacity, and peak expiratory flow rate, have been reported. Reduction in level of biomarkers indicative of oxidative stress have been observed along with enhanced glucose tolerance following regular practice of Suryanamaskar.[3,10] Improvement in muscle mass and reduction in fat mass are some of the benefits attributed to Suryanamaskar intervention.[1] Sinha *et al*., in 2004, reported a 2.711 kcal/min increase in energy consumption from baseline to eighth posture concluding that Suryanamaskar is an ideal aerobic exercise utilizing slow stretches and placing optimal stress on the cardiorespiratory system.[11]

Regarding biomechanical demands of yogasanas, previous researchers have reported kinetics, kinematics, and muscle activity during standing yogasanas in elderly individuals.[12] Graded biomechanical stress placed by initiating training with supported and progressing to traditional unsupported tree pose, warrior pose, dog pose, and chair pose produced lower joint moment of force in the sagittal plane by 30%–268% during supported asanas. However, supported asanas generated lower muscle activity whereas traditionally performed asanas generated greater muscle activity and consequently greater joint moments which were however low moderate. Most standing asanas targeted quadriceps femoris, gluteus medius, erector spinae, and generated 70% greater activity in rectus abdominis than walking activity.[6,12,13,14]

With respect to biomechanics of Suryanamaskar, the smooth rhythmic kinematic transition from one posture to another along with mathematical model to predict loads on the wrist, elbow, shoulder, hip, knee, and ankle joints are reported.[15] Low loading stresses placed in unique distribution patterns are described suggesting that none of the joints are overloaded while performing Suryanamaskar.[15,16] In addition, improvements in fatigue, balance, gait speed, and stride length are reported using clinical measures.[17,18,19,20]

Thus in conclusion, there is still paucity of information on biomechanical demands of Suryanamaskar using robust biomechanical exploration regarding precise joint angles, range of motion, and center of mass (COM) trajectory offered during individual poses of Suryanamaskar is deemed necessary to inform clinicians and yoga practitioners to enable the inclusion of Suryanamaskar in routine healthcare. Therefore, the present study aimed to explore temporal variables, COM trajectory, and kinematics of Suryanamaskar.

Methods

Following approval from Ethical Committee for Research on Human Participants, MGM Institute of Health Sciences, Navi Mumbai, 10 healthy trained yoga practitioners (five males, five females) were recruited. All participants provided informed consent as per the Declaration of Helsinki guidelines. The participants were screened for known musculoskeletal, cardiovascular, respiratory, metabolic, and neurologic disorders. Following screening and informed consent, the participants were instructed to perform the described 12-pose sequence poses during motion capture.

The 12-pose sequences of Suryanamaskar were as follows: Pose 1–Salutation Pose (Pranamasana), Pose 2 – Raised Arm Pose (Hasta uttanasana), Pose 3 – Hand-to-Foot Pose (Hastapaadasana), Pose 4 – Equestrian Pose (Ashwa sanchalanasana), Pose 5 – Mountain Pose (Parvatasana), Pose 6 – Eight Limb Pose (Ashtanganamaskara), Pose 7 – Cobra Pose (Bhujangasana), Pose 8 – Mountain Pose (Parvatasana), Pose 9 – Equestrian Pose (Ashwa sanchalanasana), Pose 10 – Hand-to-Foot Pose (Hastapaadasana), Pose 11 – Raised Arm Pose (Hasta uttanasana), and Pose 12 – Salutation Pose (Pranamasana) [Figure 1]. Consistency in the performance of sequence was maintained, as the participants belonged to and practiced different forms of Suryanamskar. All participants were certified yoga practitioners, practicing Yoga for >5 years. In routine practice, seven followed traditional school of Yoga which practiced a sequence similar to the one described in our study whereas three followed nontraditional school of Yoga (where Pose 5 was plank pose in which trunk is maintained parallel to the ground instead of parvatasana (mountain pose) in which the hips remain flexed in inverted V position). However, in this study, all practitioners performed the poses as shown in Figure 1.

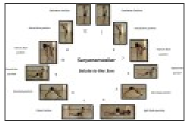

Figure 1

Twelve-pose cycle of Suryanamaskar

The participants performed two practice trials before testing. The participants were tested in suitable body suits to permit unobtrusive motion and prevent obstruction of markers. They were instructed to attain and hold each pose for 1 s.

Three-dimensional motion was captured with 12-camera Vicon system (Oxford Metrics Group, UK) at a sampling frequency of 100 Hz using 39 retro reflective markers [Figure 1]. Markers were secured with double-sided adhesive tape on predetermined anatomical landmarks defined by the plug-in-gait model. The markers were placed bilaterally on front forehead, back forehead, tip of shoulder, upper arm, lateral epicondyle of elbow, forearm, ulnar and radial styloid processes, anterior superior iliac spine, posterior superior iliac spine, lateral aspect of thigh, lateral condyle of femur, lateral aspect of tibia, lateral malleolus, posterior aspect of heel, second metatarsal head and at C7, sternal notch, xiphoid process of sternum, T10, and right scapula.[21] The static trial was recorded while standing in anatomical position to enable calibration. Five dynamic trials of Suryanamaskar were captured, and data were processed using plug-in-gait model. Analog data were filtered at 10 Hz. Joint angles during 12 poses were computed within Vicon Nexus. Kinematics of the 12 poses is described further.

Results

Temporal variables and kinematics of spine (C7-L5), hip, knee, and ankle joints, and upper extremity in sagittal plane during all 12 poses of Suryanamaskar are [Table 1]. Total time taken to perform the entire 12-pose sequence was approximately 44.83

(7.27) s. The total time required to attain a pose including hold time was 2.5–5.5 s. COM of the body was observed to rise and fall with the poses with the highest position attained during raised arm pose 94.7 (4.6) cm whereas COM was the lowest during eight-limb pose 15.1 (2.5) cm.

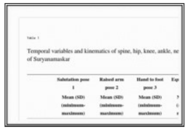

Table 1

Temporal variables and kinematics of spine, hip, knee, ankle, neck, shoulder, elbow and wrist during 12 poses of Suryanamaskar

Movements were observed to be largely symmetrical in all poses except equestrian pose which was reciprocal. The spine moved through relative flexion and extension during the symmetrical poses. Overall, in the symmetrical poses of Suryanamaskar, the spine moved through a range from 58° flexion to 44° extension alternating between flexion and extension and remained in intermediate range of flexion while maintaining asymmetrical poses. Peak extension of 44.1° ± 8.8° is attained during the raised arm pose whereas the peak flexion of 57.6° ± 16.3° is attained during the hand-to-foot pose. The spine moves through intermediate flexion movement through Suryanamaskar. Extension of 12.9° ± 22.1° is achieved in eight-limb pose and cobra pose 30.4° ± 40.5°. During the asymmetrical equestrian pose, the spine remains in 12°–14° flexion [Figure 2].

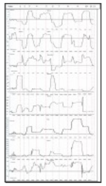

Figure 2

Spine, hip, knee, ankle, neck, shoulder, elbow, and wrist motion during Suryanamaskar

During the symmetrical poses, hip joint was observed to move from 130° flexion to 15° extension, achieving maximum flexion of 82.8° ± 9.5° during hand-to-foot pose and maximum extension of 15.2° ± 7.8° during cobra pose. However, peak hip flexion was attained while maintaining the asymmetrical equestrian pose 134.4° ± 23.0° on one side with slight hip flexion of 15.6° ± 0.31° on the opposite side. Some of the participants (50%) were observed to achieve hip extension during this pose on the opposite side hip extension [Figure 2].

During the symmetrical poses, maximum flexion of 29.9° ± 13° at the knee was achieved during eight-limb pose whereas slight hyperextension 3.9° ± 5.2° was seen during salutation pose. Peak knee joint flexion of 109.8° ± 27.3° was observed during the asymmetrical equestrian pose in combination with peak hip flexion [Figure 2].

Ankle was observed to move in a closed kinematic chain through a maximum of 30.5° ± 11.4° dorsiflexion during mountain pose to 5.7° ± 3.4° relative plantar flexion during hand-to-foot pose [Figure 2].

The neck was observed to remain in extension through most of the poses except for those which demanded greater flexion at the lumbar spine – hand-to-foot pose and mountain pose. Peak neck extension of 76.9° ± 17.0° was achieved during cobra pose whereas the least amount of extension of 1.9° ± 17.8° was observed during mountain pose. About 60% of participants achieved neck flexion during this pose. The asymmetrical equestrian pose demanded 60° of neck extension.

Shoulder joint achieved a peak flexion of 54.6° ± 1.7° during the hand-to-foot pose. While full overhead extension beyond 180° was achieved during raised arm pose. Elbow was observed to flex maximally to 113.2° ± 7.58° during namaskar pose and eight-limb pose (116.3° ± 17.0°) while least flexion was observed during the mountain pose (22.3° ± 5.0°) and hand-to-foot pose (23.4° ± 3.7°). The highest wrist extension of 85.4° ± 13.4° was observed during eight-limb pose whereas the least extension was observed during hand-to-foot pose (3.1° ± 69.2°). However, it was observed that the wrist showed greatest variability in motion with wide standard deviations.

Discussion

This is the first study to report precise joint angles at the spine, hip, knee, and ankle in the sagittal plane. Temporal variables and kinematics of poses attained during Suryanamaskar and factors which might influence kinematics are discussed below.

Suryanamaskar involves movements of all body segments and is a promising model of whole-body exercise. Each sequence of Suryanamaskar was accomplished in a range of 37–51 s, with an average of 44.8 s/sequence. One sequence of gentle exercise which mobilizes almost all body joints in <1 min holds huge potential for prescription as mobility exercise for people with time and space constraints typical to the hectic urban lifestyle globally. Moreover, the time taken for achieving each pose along with transition to the next pose was fairly well distributed ensuring that loads were not sustained on one joint for prolonged duration of time.

In addition, COM travels through a wide range vertical trajectory of 79.3 cm from the lowest position of 15.1 cm from ground to a highest position of 94.7 cm during the complete sequence of Suryanamaskar. In comparison, walking on a level surface produces an average vertical displacement of 4.4 ± 1.2 cm of COM, which is 18 times smaller displacement. Yet, walking is known to demonstrate improvement in postural sway.[17,18] Moderate walking activity three times/week for 2 km regularly has demonstrated improved postural sway in elderly people.[19] Therefore, we speculate that Suryanamaskar which produces 18 times greater vertical displacement of COM than walking, can challenge postural control mechanisms to a greater extent than walking. Therefore, Suryanamaskar holds potential for application of training stimulus for postural control in people with impaired balance.

Kinematically, Suryanamaskar was observed to be largely symmetrical following a graceful sequence of poses that moved the spine and lower extremity joints through a near complete range of motion. Predominant motion in the sagittal plane, alternated between flexion and extension. All involved joints were observed to move through a large range of motion which would be effective in stretching muscles and soft tissue. Flexion of the spine during pose 3 would exert a stretch on posterior structures such as dorsolumbar fascia, hamstrings, and tendoachilles whereas the extension of the spine and hip would stretch iliopsoas. In addition, alternating flexion-extension movements would ensure alternate distribution of compressive forces at the spine, which could be beneficial contrary to certain exercises, which have either a flexion or an extension bias and are likely to produce compressive forces on anterior or posterior structures of the spine, respectively.

Complete knee flexion up to 132° ensures stretching of the quadriceps muscle while movement of ankle in a closed kinematic chain through 32° dorsiflexion effectively stretches the gastrocnemius and soleus. These findings substantiate the reports of increase in muscle flexibility following the Suryanamaskar intervention.[1,22,23] In addition, alternating flexion-extension movements may ensure even distribution of compressive loads on spine and lower extremity. Thus, Suryanamaskar holds potential to increase the mobility of almost all body joints, with a stretch on anterior and posterior soft tissues. Joint moments encountered by various joints during Suryanamaskar are reported to be highest at the hips.[11,16] It is speculated that submaximal loading of joints compared to other high-impact activities such as running, along with comparable energy expenditure make Suryanamaskar a suitable exercise option for improving strength and mobility in people with degenerative musculoskeletal disorders, as none of the joints seem to be overstressed.

Similarly, the upper body quadrant also demonstrated a wide range of movement. Neck extension during most poses with a maximum of 76° could be beneficially used in people involved in desk jobs demanding continuous flexion activity and subsequent development of neck pain. Shoulder moved through overhead extension of 183°–56° flexion, elbow from 22° to 116° flexion, and wrist from 85° to 3° wrist extension; demonstrating that alternating wide-range transition between flexion and extension during Suryanamaskar has the potential to increase mobility of all joints throughout the body, stretch anterior and posterior soft tissues, and challenge the postural balance mechanisms through a varying base of support. Given, wide and large range of motion offered, Suryanamaskar holds huge potential as a single complete exercise to enhance flexibility and postural control of the body in a closed kinematic chain to impart benefits of weight bearing.

The wide range of motion observed during Suryanamaskar may be influenced by inherent joint laxity or greater soft-tissue length which may explain knee extension range beyond neutral. Wide standard deviation in angles in some of the poses may be due to inherent variation in technique and greater awareness of joint position sense in some people compared to others. Studies report improvement in balance performance following Suryanamaskar intervention in healthy as well as people with neurological disorders which may be due to enhanced joint position sense following training.[1,20]

The present findings inform the principal motion in sagittal plane. There is further scope to discuss coupled motion in coronal and transverse planes.

Findings from the present study offer robust insight in kinematics of Suryanamaskar, providing precise information on joint motion occurring at spine, upper extremity, and lower extremity joints to enable clinicians to offer evidence-based prescription of Suryanamaskar.

Conclusion

It is concluded that alternating wide range of transition between flexion and extension during Suryanamskar holds potential to increase mobility of almost all body joints by stretching anterior-posterior soft tissues and challenge postural balance mechanisms through a varying base of support.

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Conflicts of interest

There are no conflicts of interest.

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Influence of Varying Squat Exposure on Knee Pain and Function among People with Knee Osteoarthritis

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ABSTRACT

Knee osteoarthritis (OA) is a leading cause of pain and functional disability globally. Knowledge about the influence of high-flexion postures on knee function among people with knee OA is limited. Sustained occupational squatting is assumed to increase tibio-femoral and patella-femoral compressive force and knee osteoarthritis. Additionally, people spend varying amounts of time in deep squat for performing self-care, activities of daily living (ADL), and leisure. Hence, a study was conducted to explore the influence of varying squat exposure on knee pain and function. An interview-based survey was conducted inclusive of 300 participants, following institutional ethical approval and informed consent. Participants were classified based on daily squat exposure using a validated tool: the MGM Ground Level Activity Exposure Questionnaire. Knee pain and function were assessed using the Numeric Rating Scale and the Modified Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), respectively. Thirty-three people from the study cohort (Nonsquatters n = 13, ADL squatters n = 10, occupational squatters n = 10) were evaluated for knee motion, muscle strength, and balance using 2D motion analysis, 30-second chair-stand test, calf-raise test, 30-second deep-squat test, single-leg stance test, and star excursion test, respectively. Prevalence of knee pain was 27% in squatters and 21% in nonsquatters. People with higher squat exposure demonstrated greater knee motion, muscle strength, and balance compared with nonsquatters. Occupational squatters continued to work on a higher level of function despite pain and difficulty. Deep-squat activity performed in moderation is a potentially beneficial activity to maintain knee range, muscle strength, and balance.

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Gait Deviation Index of Children with Cerebral Palsy with Severe Gait Impairment

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ABSTRACT

The gait deviation index (GDI) is a comprehensive tool derived from three-dimensional gait analysis providing averaged kinematic data from the pelvis, hip, knee, ankle, and foot. It guides clinicians in quantifying intervention efficacy over time by informing gait performance and magnitude of kinematic change in gait pattern. Severity in motor disability is associated with decreased GDI. However, the lack of information on the GDI of children with severe gait impairment characterized by high crouch angle (> 20°) motivated our group to explore GDI at different levels of the gross motor function classification system (GMFCS). Forty-seven ambulatory children (5–18 years) with cerebral palsy (CP) (28 males; 19 females) with a mean crouch angle 20.15° were compared with 45 normally developing healthy children. The GDI of children with CP was 25% lower than that of age-matched healthy children and 13%–27% lower than that of children with less severe crouch angle (2.2°–18.9°) at similar functional levels reported in the literature. Significant linear decline was observed in GDI across GMFCS I (70), GMFCS II (65.42), and GMFCS III (44.6). Out of nine kinematic variables computed to calculate GDI, minimum knee flexion in stance was three times greater (6.9°) among children at GMFCS I and two times greater (16.1° and 37.39°, respectively) among children at GMFCS II and III compared with children at similar GMFCS levels reported in the literature. This is the first study to report GDI of children with CP characterized by greater crouch angle at varying GMFCS levels. The sensitivity of GDI in detecting minimal clinically important differences can guide physicians and health care professionals in monitoring the outcome of surgical and nonsurgical interventions in children with CP.

Gait Kinematics of Bharatanatyam Dancers with and without Low Back Pain

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Abstract
Bharatanatyam dance involves complex symmetric and asymmetric poses performed in a maximal arc of motion which may result in kinematic changes reflected in a common weight-bearing activity such as gait. Prevalence of low-back pain among dancers has been reported to be 43.5%. The aim of this study was to investigate the kinematics of gait to understand musculoskeletal adaptations among Bharatanatyam dancers, and thus gain an understanding of the pathomechanics of spine pain. Seventeen active Bharatanatyam dancers with eight years of formal dance training formed Group A. Group B included dancers with chronic mechanical, nonradicular low-back pain, and Group C included healthy age-matched nondancers. Gait kinematics was recorded using 12 infrared cameras and 3D motion analysis. Participants were instructed to walk five times at a self-selected walking speed on a 10-m walkway. Midgait data were processed in Vicon Nexus 2.4 to obtain peak joint angles of spine, pelvis, hip, knee, and ankle. Intergroup analysis was performed using the Kruskal-Wallis test. Dancers with low-back pain exhibited 20% greater spine extension, 35% greater anterior pelvic tilt, and 30% lesser pelvic rotation compared to dancers without low-back pain. Kinematic demands of typical dance postures resulted in increased spine extension, exaggerated anterior tilt, and obliquity of the pelvis. Implementation of a specific exercise program designed to neutralize excess deviation at the pelvis and spine may result in strength and conditioning effects to safeguard the lower back.

Survey of Musculoskeletal Disorders Among Indian Dancers in Mumbai and Mangalore

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- Abstract

Classical Indian dance has earned recognition across the globe; however, the health of dancers who are carrying forth this heritage has not received due attention. Therefore, this study aimed to explore musculoskeletal pain and injury prevailing among Indian dancers in Mumbai and Mangalore. A secondary aim was to compare pain tolerance levels between dancers and non-dancers. Fifty-one dancers trained in different traditional Indian and Western dance forms and 164 recreational dancers were recruited as participants. An indigenous questionnaire was designed and validated by physical therapists across various levels of experience and dancers across various training levels. The questionnaire recorded dance, pain, and injury profiles. Additionally, pain tolerance was evaluated using the Pain Sensitivity Questionnaire among dancers and healthy age- and gender-matched controls (N = 200). Descriptive statistical analysis was performed to present results of the site of current pain, site of past injury, perceived causes of injury, and exercise routine. The Student's t-test was used to compare Pain Sensitivity Questionnaire scores between dancers and non-dancers, and independent one-way ANOVA was used to compare scores among dancers practicing different dance forms. For both current pain and past injury, dancers reported the back (42.5%) followed by the knee (28.3%) and ankle (18.6%) as the most common sites. Stress was the most commonly perceived cause of injury (34.4%), followed by over work (24.7%), tiredness (17.2%), and falls (13.5%). Warm-up exercises were always performed by 43.30% of dancers, whereas only 20% performed stretching after dance. Almost 60% of dancers participated in forms of exercise other than dance, e.g., swimming, yoga, and aerobics. Pain sensitivity was not significantly different between dancers and non-dancers (p = 0.159). Level of training and gender did not influence pain.

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Evaluation of Daily Walking Activity in Patients with Parkinson Disease

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ABSTRACT

Parkinson disease limits walking, and little is known about the performance of walking and factors that influence the quantum of walking in active, city-dwelling patients with mild to moderate Parkinson disease in an environment characterized by extended family support but limited access to public spaces. An exploratory study was performed to evaluate daily walking performance and the influence of an intrinsic factor—namely, balance during standing—and the extrinsic factors habitual physical activity and health-related quality of life in people with Parkinson disease. Daily walking activity was recorded with a step activity monitor for 8 consecutive days in 15 patients with Parkinson disease (Hoehn and Yahr scale score, 1–3). All patients were actively engaged in physiotherapy. We also recorded data from 15 age-, sex- and height-matched healthy individuals. Mean number of daily steps, duration of ambulatory activity, and gait speed were recorded. The Unified Parkinson's Disease Rating Scale, the International Physical Activity Questionnaire, and the World Health Organization Quality of Life BREF instrument were administered. Mean number of daily steps did not vary significantly between patients with Parkinson disease who exercise regularly (7018.80 ± 4068.58 steps per day) and healthy individuals (7409.33 ± 3094.15 steps per day; no significant difference; $P = 0.40$). However, patients with Parkinson disease demonstrated 17% lower engagement in long-duration activity and a 47% lower score on the physical activity domain of the World Health Organization Quality of Life BREF instrument. A moderate positive correlation was observed between balance during tandem stance and mean number of daily steps.

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Lower Extremity Muscle Strength and Endurance in Ambulatory Children with Cerebral Palsy

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ABSTRACT

Muscle weakness in children with cerebral palsy (CP) results from reduction in central activation and abnormalities in neural maturation along with a disorganized motor recruitment pattern. Inability to produce isolated maximum voluntary muscle contraction from individual muscles results in stereotypical movements, consequently, early fatigue during ambulation causing further deterioration in muscle endurance. Limited information on lower extremity muscle strength and muscle endurance drove the present study with a purpose to inform clinician variation in lower extremity muscle strength and endurance in children with CP compared to typically developing children to improve ambulation. Thirty children with CP (15 males, 15 females, GMFCS level I–II) and 30 age-matched healthy children were evaluated for muscle strength and endurance using functional tests such as 30-second chair stand test, step-up test, timed up and go test, timed floor to stand test, 30-meter walk test, calf-raise test, and 14 stair climb test. Performance of children with CP was 54–73% lower on all tests compared to healthy children. In conclusion, markedly lower strength and endurance of all major lower extremity muscle groups, namely, hip flexors, hip extensors, hip abductors, knee extensors, and ankle plantar flexors, reiterates a strong need for objective functional evaluation and targeted training to improve ambulatory performance in children with CP. Gender and GMFCS level did not influence strength-endurance evaluation.

KEY WORDS: cerebral palsy, children, muscle strength, muscle endurance, lower extremity, ambulatory children, Gross Motor Function Classification System (GMFCS), functional tests

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Development of the Deep Squat Milestone in Typically Developing Children

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ABSTRACT

Deep squat is a functional activity recruiting multiple muscle groups in a single maneuver with huge potential value in pediatric rehabilitation following neuro-musculo-skeletal dysfunction. Explicit mention of development of the deep squat milestone in gross motor development is difficult to trace in the literature. For this reason, the current study was designed to explore development of the deep squat milestone, patterns of movement adopted for attainment, and lower-limb joint motion during deep squat in typically developing children. Following ethical approval and parental consent, data were recorded from 12 normally developing children, aged 6-13 months, using video cameras in the natural environment of each child every consecutive month. Hip, knee, and ankle joint angles were computed using Silicon Coach software. Descent of squat was attained first, followed by ascent from squat one month later. The average age at which typically developing children initiated supported/unsupported descent to deep squat was 11 months; supported ascent from squat was initiated at 12 months. Ascent from deep squat to upright posture was broadly noted from three initiating postures: bear followed by half kneeling and then supported squat. Timing of ascent from squat was observed to be one month after reported attainment of pull-to-stand reported at 11 months. Our study suggests that evaluating attainment of the deep squat milestone will prove immensely valuable in pediatric rehabilitation, in view of poor eccentric control of lower-limb postural muscles in children with gross motor dysfunction disorders such as cerebral palsy.

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Functional Outcome Following Lower Extremity Amputation: A Review of Contextual Factors Influencing Function in Low- to Middle-Income Group Countries

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ABSTRACT

Lower extremity amputation (LEA) leads to reduced mobility and walking capacity. Contextual factors influencing activities of daily living and community participation in people with LEA vary in low-, middle-, and high-income countries. In the present study, we aimed to review contextual factors influencing function of people with LEA in low- to middleincome countries. A literature search for articles published between January 2000 and 2018 was carried out using PubMed, Google Scholar, and Cochrane reviews databases. In total, 27 relevant articles were identified and reviewed: 8 qualitative studies, 4 manuals and factsheets, 10 descriptive cross-sectional studies, 2 comparative studies and 1 survey. Several external contextual factors were strongly linked with poor functional outcome, dissatisfaction, and participation restriction: lack of awareness and inadequate rehabilitation and prosthetic services; lack of social security systems; health insurance; poor quality and durability and high cost of prostheses; poor transport facilities; and level of education in low- to middle-income countries. Low income, inaccessible environment, and social stigma associated with amputation reduced functional outcome and community participation. Internal factors like poor coping strategies, negative self-esteem, old-age, female gender, and negative body image were linked with poor functional outcome, whereas strong family support improved participation of people with LEA.

Our review highlights a strong need to build greater awareness on rehabilitation measures following amputation and need for disability inclusive environment to promote community participation in low- to middle-income countries.

KEY WORDS: lower-limb amputation, contextual factors, developing countries, low to middle income countries, quality of life, function, rehabilitation, prosthetic services

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Review of Lower Extremity Function Following SEMLS in Children with Cerebral Palsy

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ABSTRACT

Single-event multilevel surgery (SEMLS) is aimed at improving gait and motor function to optimize movement patterns, promote motor skill acquisition, and improve mobility. Literature informing comprehensive evaluation of post-surgical outcome based on the International Classification of Function (ICF) model (a standard framework for describing and organising information on functioning and disability) are lacking. We have summarized this review to guide clinical practice and have developed recommendations for future research. A literature search was performed in PUBMED, Google Scholar, and Cochrane database in July 2018. We included longitudinal, comparative, cross-sectional, prospective, retrospective, and systematic reviews reporting functional outcomes post-surgery with a mean follow-up period of minimum of 12 months on cohort of children aged 4−18 years with spastic cerebral palsy (CP) were included. We excluded articles reporting upper limb functional outcome, functional outcome of single surgical procedure, surgical approach, and functional outcome of only soft-tissue release. Of 43 extracted studies on post-surgical outcome, 16 met our inclusion criteria. According to the Physiotherapy Evidence Database (PEDro) scale, 4 articles were of high quality and 12 studies were of fair quality. SEMLSs demonstrated improvement in sagittal plane gait kinematics of all three lower extremity joints (hip, knee, ankle). Maximum improvement of approximately 5−28° was noted in minimum knee flexion (i.e., range of motion, ROM) during the stance phase. Improvement in gait profile score was maintained 5 years post-SEMLS. Mobility on functional mobility scale deteriorated at the first 6-month followup post-SEMLS, followed by an improvement at the 24-month follow-up. Postoperatively, self-care continued to improve over 18 months. Although improvement was reported in gait, mobility, and self-care, clinically meaningful improvement was not noted in quality of life. Our review suggests that, following SEMLS, improvement is reported in isolated outcome variables of function such as gait, mobility, and self-care. However, comprehensive evaluation of functional outcome needs further evaluation based on the ICF model.

KEY WORDS: functional outcome, international classification of function, single-event multilevel surgery, cerebral palsy, gait, gait profile score, gross motor function classification system three-dimensional gait analysis, quality of life, mobility

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