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Review Article

Human Gait with Reference to Age, Gender and Impact of Load: A Review

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Abstract: This review paper summarizes the available literature regarding the analysis of human gait of with reference to age and its effect on the performance. The ability to walk upright on two legs (bipedalism) is the root of what it means to be human and each person displays personal peculiarities in their walking pattern. According to the studies, muscle activity changes with the deviation of gait pattern in different condition and even for different individuals. It has been found that a vivid knowledge about the kinetics and kinematics of human gait improves the understanding of proper mechanisms of walking and has found to be helpful. Studies also suggest that the determinants of gait from decades are never closely being observed which is needed and can be productive. Gait is altered by different factors especially age, gender, working conditions etc. Walking pattern or more precisely the parameters of gait are affected by different load carriage conditions. Aging has a great impact on gait variability. With increase in age gait parameters like step length becomes smaller and step width also becomes wider, even pelvic mobility also decreases which in turn slower the walking speed. A significant difference of gait initiation speed, hip and knee angles has been found between males and females. A few studies have shown a wide range of differences of human walking pattern between different populations. It varies from country to country, even region to region in a particular country due to differences found in the body composition which is again affected by various important factors like climate, food habit, landscapes etc.

Keywords: Gait, Load Carriage, Ageing, Industries

1. Introduction

Walking, a crucial activity of daily life, is a mode of bipedal locomotion in which a period of double support, i. e when both feet are in contact with the ground, is followed by a period in which the body is supported by one lower limb while the other is swung forward [1]. The suitable role of human gait analysis in daily work remained a matter of discussion, as walking is a basic requirement for daily activity and heavy manual work. Walking can adapt to a wide variety of environmental conditions [71]. It is known to be one of the most general and complex of all human activities. Gait is the manner of walking. This implies that we do not all have an identical walking pattern. The most common measurements of gait are the temporal-spatial parameters which include walking speed, stride time and length, step time and length, stance phase and swing phase. These are also regarded as the basic gait parameters or the vital signs of walking [65, 66, 53]. These measurements are very useful indicators of gait pattern indicating the cause of any existing problem. Many authors studied the influence of walking speed on gait parameters to and out their normal ranges [18].

Many investigators have studied the inter subject gait differences in normal samples; some are based on measurements of one or more of the temporal-spatial parameters. Perhaps the most frequently studied differences are those associated with age [54, 23]. However, numerous other normative studies have been undertaken to determine the effects of different variables like walking speed, height or leg length, footwear, and curb clearance.

Since human kinetics is a complex activity encompassing the limb movements, muscle activity and neuromuscular coordination, external and internal forces acting to provide balance and stability and energy conservation, a mere visual inspection of it will not suffice, it needs both qualitative and quantitative techniques to analyze it which will enable a researcher or a practitioner (professional) to understand the age wise as well as gender and work condition wise biomechanical changes in industrial activities, hence there is a need to review the literatures to know what kind of studies has been done on this and what are the future scopes in this field. Thus the review of literature on the impact of age related changes on human kinetics along with impact of load carriage in different professions has been classified under following categories

2. Review of Literature

2.1. Basic Concepts of Gait and Human Locomotion

Reference [3] studied that over the past years the evolution of gait science had produced a number of terms and concepts related to observational gait analysis. According to him, normal bipedal locomotion was a combination of automatic and volitional postural components. Normal walking required stability to provide antigravity support of body weight, segmental mobility of body and motor control to chain diverse segments while shifting body weight from one limb to another which actually required energy efficient forward progression. Reference [61] explained bipedalism as unique human characteristics that distinguish them from apes. It required lower limbs to support all the body weight and balance against gravity and it influenced an individual's participation and interaction in society. Normal human locomotion consists of conventional movement patterns that are right away recognizable.

2.2. Muscle Activity During Gait

Reference [5] studied that muscle activity, found out of phase during walking may characterize abnormalities and this can be obtained by a recording of the dynamic electromyography during walking. Conditions such as neural injury or compression, denervated muscle or primary pathological process causing gait deviation could be identified with the dynamic electromyography during walking and this was again proved by reference [52]. Reference [69] observed that the changes in muscle activity and length, joint angles and torques could be variable not only across speeds and subjects, but even from trial to trial in human. Reference [2] studied and found that the rest of the work not done by muscles required for walking is contributed by passive force through joints and bones. Reference [26] studied that when walking, people generated a certain amount of force each time they placed the foot on the ground and in return received same amount of force from ground and this was called ground reaction force (GRF). GRF was greater than body weight both early on in stance, while the body was accepting weight, and during late stance, during push off but in mid stance the GRF was lower. Even Reference [9] found the same muscle activity during walking and concluded that muscles mainly function to accelerate and decelerate leg. Reference [20] concluded after vivid research that the magnitude and duration of muscle activity increased when subjects walk up an incline. Reference [27] studied five muscle activities during human locomotion and found a great deal of inter subject and inters muscle variation. Reference [38] estimated medial and lateral loading for people with knee osteoarthritis and healthy group using subject specific muscle activation patterns. It can be concluded that although walking is not a simple activity, it was actually a tangled series of co-ordinated movements of muscles and joints of the upper and lower extremities.

Reference [44] also studied visual effect, muscular fatigue, task performance and working experience on inclined surfaces on activity of lower limb postural muscles rectus femoris, biceps femoris, tibialii anterior and gastrocnemii medial muscle groups associated with maintaining balance by normalised electro myo graphic (NEMG) data.

2.3. Normative Data and Comparative Data on Human Gait of Various Countries

Many significant differences between Kuwaiti and Swedish subjects in their walking pattern in terms of gait parameters [1]. Reference [62] also compared the gait characteristics between Korean and Western people and found that the stride length and walking speed of Korean subjects were significantly lower but the knee abduction moment was larger than those of Western people. Hip moment in the sagittal and frontal plane, knee and ankle moment in the sagittal plane were found to be smaller than those of Western people. Ranges of motion showed no significant changes.

Reference [30] presented a simple external marker system and algorithms for computing lower extremity joint angle motion during level walking and implemented on a computer-aided video motion analysis system (VICON). Data of angular motion of knee, hip and ankle joints were collected from 40 healthy individuals and those were useful as a reference data for describing and comparing pathologic gait. Reference [53] extracted basic gait parameters for slow, normal, and fast gait from 116 healthy men and 117 healthy women of 10 to 79 years and a reference data were formed which was considered valid in an indoor laboratory situation. Influence of sex was highly significant. Significant age related changes in gait parameters were observed. A similar normative data or a reference data for the joint angle parameters on the same population were established by the same authors in the year 1994. Reference [63] had created acceleration-based reference database for healthy gait on Netherland population. The repeatability and inter-observer reliability of acceleration-based gait analysis was investigated and found to be advantageous for routine clinical use and in daily life. Reference [58] presented a gait-speed related reference data for basic kinematical spatio-temporal and angular parameters during human normal gait.

2.4. Impact of Load Carriage on Human Gait Pattern

Reference [46] said that males and females displayed significantly different gait patterns under all load conditions. The females required more steps than the males sue to shorter stride lengths. Their walking patterns were affected by the increased load. They found decreased stride length and swing time while increased stride rate and double-support time with increased load. Gait characteristics showed lesser changes inmales and females showed greater sensitivity to load magnitude. Reference [42] examined and found that carrying load carriage around the waist was the advantageous condition. Women with strong shoulder muscles showed less trunk and shoulder deviations while carrying heavy load on back. Reference [15] examined the jounce of schoolbags on the gait pattern and trunk posture of 23 male school children of 10 years for a long duration. They commenced significant differences in trunk inclination angle, stance duration, double leg support duration, and swing duration with loads of 0% to 20% body weight.

Reference [8] studied in UK that both vertical and anteroposterior component of ground reaction force increased proportionally when load was added. Unlike many other studies significant increases in force along the mediolateral axis was observed with increased load. This showed decreased stability with greater loads. Rifle carriage caused an increase in the ground reaction force due to the forward shift in the centre of mass or more likely due to the curbed arm movements while carrying a rifle. Reference [29] also observed that the gait pattern and centre of mass were influenced by emphasised arm swing pattern. Reference [45] carried on a study on load carriage for infantry soldiers. They found that speed changed during load carriage even at self-selected speed. Stride length and cadence found to increase. Other gait parameters also were affected. Redesigning the back pack for reducing the kinematic stress of the individual was necessary due to increased joint angular changes, range of motion and excess forward inclination of trunk.

Reference [39] studied and found that both high-heeled shoes and asymmetrical load carriage caused alterations in temporospatial parameters, joint kinematics and kinetics during walking. Women walking with high-heeled shoe and load carriage had adaptive strategies to maintain stability and to carry on steps for ambulation. Kinematics and kinetics changes at the lower extremity caused by the combined high-heeled shoes and load carriage might be a considerable factor of potentially injurious forces that might underlie some of the joint pain complaints of high-heeled shoes users. Reference [40] also found that walking with high heel shoes and asymmetrical load carrying altered the lower extremity kinetics. When high-heeled shoes and asymmetrically carried load were combined, the changes of joint kinetics at each joint were much greater than that caused by the high-heeled or load carriage alone.

Reference [33] studied and found while carrying backpack load, students wanted to shift the centre of gravity of the body as well as backpack system back by increasing the forward lean angle. Counterbalance backpack allowed person to upright position, by shifting the centre of gravity of the load forward. Considering the kinematic and ergonomic of load carriage the counterbalance backpack had significant benefits.

2.5. Influence of Age and Gender on Human Gait Pattern

Reference [28] tried to investigate the differences in the gait of young and old men and women and to produce a table of normal values with information regarding temporal factors, ataxia and external work. Reference [23] found that elderly women demonstrated significantly smaller values of step length, stride length, velocity, angles, and range of motion, pelvic obliquity compared with the younger women.

Reference [69] studied and found that the natural walking velocity of the elderly subjects was significantly reduced due to decrease cadence and increased double-support stance time. The significant differences in gaitattributed to an adaptation related to a safer (less destabilizing) gait. Reference [68] also found that walking pattern of elderly men were different from young adults. Reference [43] found that changes in gait parameters associated with ageing initiates slips and falls when examined on 28 subjects (young and elderly). Reference [48] found that aging significantly changed the gait pattern of the healthy elderly. According to reference [55], step width variability of older adults was significantly larger than that of young adults. A consistent relationship between age and step width variability were observed. Since step width variability had been implicated in falls, further research was warranted. Reference [32] again found that the greater variability observed in the gait of older adults might result more from loss of strength and flexibility than from their slower speeds.

Reference [70] after working on 100 different samples found that people could be identified according to gender by their walking pattern. He tried to describe an automated system that classified gender by utilising a set of human gait data. Reference [60] found that the main kinematics differences between male and female walking patterns were dependent on the hip joint. The flexion posture and the greater frontal balance were natural characteristics of the female group and influence the frontal movement of the ankle. The major flexion of the male knee was another difference in relation to the female group. The frontal orientation of the male and female knee was in agreement with their anatomical structure and no significant movements were measured in this plane also.

Reference [64] found changes in movement amplitude with age in response to speed manipulations for all segments and joints. Trunk flexion-extension in sagittal plane and pelvic rotations in all planes of motion were reduced and trunk axial rotation increased with age leading to reduced compensatory movement between pelvis and trunk in older individuals. Reference [56] found that elderly group had a significantly shorter step length and wider step width, lesser range of motion compared to the results of a young control group during walking. Reference [34] said that the healthy elderly people walked more slowly than the young adults caused by their shorter stride length and shorter single-leg balance lesser steps and speed than the young adults. The stance time increased with age as an adaptive feature. Reference [12] studied the temporal and spatial gait variability of 412 subjects of 60–86 years and found that age was linearly linked with greater intra-individual gait variability for most gait measures, except for step time variability in women. Gait speed might mediate the association between age and temporal variability measures. Reference [21] suggested that gait speed differences between men and women might be for size rather than sex. They identified a possible increase in many gait metrics between 20 to 40 years of age, before decreasing around the fifth decade of life. They suggested future studies to examine these trends across the entire lifespan.

2.6. Work Related Lower Limb Problems

Musculoskeletal disorders are a major problem among industrial workers. Many ergonomic studies showed that the construction industry is one of the top occupations for work-related musculoskeletal disorders (WMSDs).

Reference [7] determined the ergonomic risk factors for cumulative trauma disorders on 21 carpenters on 29 occasions at 17 different construction sites through ergonomic checklist surveys and videotaping. Based upon the combined score of postures the most stressful postures as well as work condition were determined. The lower extremity (kneeling and squatting) repetitiveness during the work was significantly higher. Reference [59] did an ergonomic investigation of the musculoskeletal disorders causing factors in construction workers, a vulnerable industry. They proposed that proper plans though found to be in practice to reduce these risks but to make more extensive use of the aids already available More extensive examination of the ergonomic risk factors of separate activity needed to be done. Reference [13] found highest prevalence of pain in the lower limbs, neck/shoulders, and upper back due to highest exposures and prolonged hand/wrist movement, standing, and lifting among woman workers.

Reference [10] surveyed the prevalence of symptoms of MSDs and its relation with work among construction occupations 750 bricklayers and 750 supervisors of Netherland. Back, knee and shoulder/upper arm were found to be the most prevalent. Reference [49] tried to investigate the work-related musculoskeletal symptoms among 389 building construction workers with mean age 34.56±8.33 years and a mean working duration in building construction as 5.76±2.68 years. Musculoskeletal complaints were recorded through a detailed clinical interview and comprehensive questionnaire and both upper and lower extremities were affected.

Reference [51] wanted to explore the factors associated with developing MSDs among construction workers through Nordic Musculoskeletal Questionnaire Distal upper limb MSDs were related to manual handling, work repetitiveness, psychosocial demands, job dissatisfaction and gender. Neck, shoulder or upper back MSDs were related to manual handling, work repetitiveness, psychosocial demands, job dissatisfaction and physical unfitness.

3. Summary and Conclusion

The method of human locomotion using limbs is known as gait [36]. Normal gait sequences are cyclic and demonstrate almost perfect periodic behavior [31]. Recently, the analysis of human motion has received a large amount of research attention. The majority of this research focuses on analysis of human gait. Human gait can contain a wide variety of data that can be used in biometrics [11], diagnosis of certain clinical issues [41, 57], reclamation from injury [50, 24] and determination of load [6].

Studies on the effects of external loads on gait can quantified and these effects are then used to observe whether an individual gait pattern is affected by an external load with age being an additional factor. Load carriage is a very common daily activity in the workplace (construction site). However, it is a common cause of injuries, including those of the knee and lower limb [19, 37]. Therefore, it is important to understand the effects of load carriage on human physiology especially lower extremity biomechanics. There are many previous studies that characterize the nature of gait and the effects that external loads have on gait [35, 25, 16, 17]. Few studies provide a method of classification for loaded and unloaded gait using kinematic data.

Balance is challenged during gait when the body is forced to make a postural alteration due to disturbances to the body and a failure to compensate posture changes that results in falls. A key to improve the balance is to increase the stability of the system. Changes in temporospatial parameters during loaded locomotion are evident from other studies as well [35, 37]. Load carriage is an important factor on stability in the dynamic environments such as during simple locomotion or balancing. From previous studies it is confident to say that the load carriage puts stress on lower extremities since the lower extremities support the weight of the body, provide the propulsive forces necessary to maintain forward movement of the body and receive the shock of foot contact. The lower extremities, especially the foot, must overcome all stresses for the movement production.

In order to prevail over the stress on the musculoskeletal system, the body may need to work harder to counter balance all the biomechanical changes. Each joint will display changes in its angle, moments of force, and power, while muscle recruitment patterns will be altered. Therefore, there is a need to understand how age, percentage of load and modes of load carriage changes the kinematics and kinetics of the gait as well as the muscle activities.

Consequently, combined effects of age, load carriage on human gait and posture adaptation will actually provide the clear picture of the biomechanical adaptation of gait by examining three-dimensional dynamic gait kinematics and kinetics.

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