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Biomechanics Specialization in Aging Science and Research: Biomechanical Gerontology or Geronto-Biomechanics?

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ABSTRACT

Aging process becomes a miserable phase of lifespan of various individuals. Gerontology and Geriatrics exclusively deal with researching complex human ailments pertinent to old age in order to overcome the challenges posed by several irreversible physiological changes occurring with aging. Inevitably, homeostasis declines and massive allostasis gets organized during aging to destroy the functional independence and survival potential. Controlling the rate of aging process is the only possible self-regulating strategy available to each individual to enjoy Morbidity-Attenuated Life Years (MALYs) but maintaining an optimal fitness competence to travel along the healthy aging trajectory is not effortlessly feasible regardless of the socioeconomic conditions. Fitness evaluations on different age groups enhances the understanding that the aging process might be a premature event among several individuals at an early age itself due to multifactorial reasons, and the biomechanical constraints displayed by such individuals expose the probable wide spectrum of postural and movement dysfunctions or disabilities of unhealthy older adults. Many such health-ruining erroneous postures and movements remain asymptomatic perilously, which when addressed during appropriate stage in life, could repair the impaired physical efficiency to sustain the abilities to counteract the effects of gravitational force on the body. The importance of early detection and rectification of such peculiar biomechanical dysfunctions should become an integral part of public health prophylaxis. The repertoire of biomechanical dysfunctions of premature unhealthy aging needs to be strongly merged with gerontology to strengthen the pursuits to retard unsuccessful aging and accomplish successful aging.

Keywords: Biogerontology, Biomechanics, Ageing Trajectory, Compression of Morbidity, Polypharmacy, Comorbidities, Successful Aging, Unsuccessful Aging.

INTRODUCTION

Aging process becomes a miserable phase of lifespan of various individuals. As a consequence of unhealthy aging, even with deteriorating homeostatic stability, worse allostasis, co-morbidities and crippling disabilities, humans can live longer but healthy aging without agonies is still possible. Successful aging is multidimensional, encompassing the avoidance of disease and disability, the maintenance of high physical and cognitive function, and sustained engagement in social and productive activities.[1] The goal of research in gerontology is to learn more about the aging process-not for the purpose of extending the life span but for the purpose of possibly minimizing the disabilities and handicaps of old age.[2] "The quest for eternal youth is as old as humanity itself. Geroscience aims at seeking innovative approaches to better identify the relationships between the biological processes of aging and the biological processes of age-related chronic diseases and disabilities, and, in so doing, we hope to understand why the former is the major risk

factor for the latter".[3] The entire life is under the influence of gravitational force. Gravity either rewards health and athleticism if humans expose their neuromusculoskeletal system adequately to the gravitational torques on a regular basis or punishes by giving diseases, biomechanical dysfunctions and unhealthy aging, if humans restrict the exposure of their neuromusculoskeletal system to gravitational torques. "Our anatomy and body functions are related to gravity; we are the result of our gravity. Neurons, bones, muscles, and the whole support system were all developed in response to gravity. The correlations between life-span and gravity are important to understand our physiological limit".[4] "Aging is a multifactorial process leading to changes in skeletal muscle quantity and quality, which causes muscle weakness and disability in the aging population. Resistance and endurance training are effective measures of exercise therapy in the elderly, which improve muscle metabolism and thereby muscle function and life quality. Muscle size is not the sole contributor to loss in physical activity in the elderly".[5] Several reversible and irreversible biomechanical dysfunctions serve as hallmarks of unhealthy aging and premature unhealthy aging but not yet widely known or integrated in the field of gerontology. Birren and Bengston point out, it is especially important that future research in aging does not become hampered by rigid disciplinary boundaries which may limit information exchange and the transfer of new developments in research design and methods of analysis.[6]

Repertoire of geronto-biomechanical dysfunctions

Overcoming the inertia at rest and during different forms of physical activity are the fundamental biomechanical challenges present throughout the human life. Inadequate exposure of human body to the gravitational torques cannot be underestimated but often overlooked in the medical profession's curriculum and health care practices. Movement and Metabolism have been naturally designed to support each other; Metabolic Operations Vitalize Existence (MOVE). Lack of essential open-kinetic chain and closed-kinetic chain neuromusculoskeletal functions in any phase of human lifespan will have disabling outcomes, though many could continue to function or stay alive, under the strength of individual-specific homeostasis. In the context of unhealthy aging, such disabling outcomes, if not noticed or scientifically intervened, usually begin as asymptomatic biomechanical dysfunctions at any age and gradually matures with accompaniment of unfavourable body composition and morbidities. Thus, premature unhealthy aging comprising irreparable aging-related disabilities is highly possible in human life. Though we have abundant literatures on aging mechanisms and its complications, the medical profession has not yet completely researched the sphere of premature unhealthy aging, unhealthy aging and healthy aging, from the biomechanics perspective. "Falls and gait instabilities are among the most serious problems facing older adults. To better predict falls, factors such as musculoskeletal strength, and sensory information influencing recovery of slips and falls should be examined".[7] "The physiologic mechanisms of muscle weakness with aging are multifactorial and arise from deficits in neural activation, reductions in the intrinsic force-generating capacity of muscle, as well as muscle wasting. Age-related loss of muscle strength (dynapenia) is only partially explained by the reduction in muscle mass (sarcopenia), and these two conditions need to be defined independent of one another".[8] "Many old adults have difficulty in performing activities of daily living, in maintenance of postural balance, and in recovering from impending falls. It is not yet fully clear to what extent these difficulties arise from age, or disease-related declines in muscle function".[9] "Advancing adult age is associated with profound changes in body composition, the principal component of

which is a decrease in skeletal muscle mass. This age-related loss in skeletal muscle has been referred to as sarcopenia. Reduced muscle strength in the elderly is a major cause for their increased prevalence of disability".[10] "Both dynapenia and sarcopenia reflect directly on older adults' activities of daily living, poor quality of life, falls and fear of falling, and the frailty syndrome and can lead to disability and mortality in older adults. The musculoskeletal system and physical capabilities might decline with aging, and the transition from plateau to decline is determined by biological timing and individual life trajectories".[11] Aging of the spine is characterized by two parallel but independent processes: the reduction of bone mineral density and the development of degenerative changes.[12] "Foot pain is highly prevalent in older people and has a significant detrimental impact on mobility and quality of life. Ageing is associated with several changes in joint physiology, including a reduction in the water content of the cartilage, the synovial fluid volume and the proteoglycans".[13] "A well-known effect of increasing age is the gradual reduction of muscle function, and thus of performance in the activity of daily living. Recent research has shown that, even among the very elderly, exercise can improve not only strength and endurance, but also balance and mobility, thus reducing the risk of falls.[14] "Gravity has an influence on physiology of living things, to the point that any variation is deleterious at long or short term, depending on the amplitude and the frequency of the variations. An excessive intensity, or an insufficient intensity, or inappropriate variations, can generate discomfort or even unease. In some case, it leads to a critical health state".[15] Disability carries negative social meaning, and little is known about when (or if), in the process of health decline, persons identify themselves as "disabled".[16] Preventative measures initiated early in life may be fundamental to negating expansion of morbidity later in life, or sustaining situations of morbidity compression.[17] The interdependence of Gravity, Disability and Morbidity in association with unhealthy aging should be the geronto-biomechanical research focus in the future. If Newton's law is slightly modified, we would obtain the equation for Fitness Excellence. Fitness Excellence = Ideal Body Mass x Ability to Counteract Gravity, but suboptimal exposure of neuromusculoskeletal system to gravitational force leads to Altered Body Composition with Disability (ABCD) – Figure 1 and Table 1.

Figure 1: Three main components of Gravitational Torque Deficiency Syndrome (GTDS).

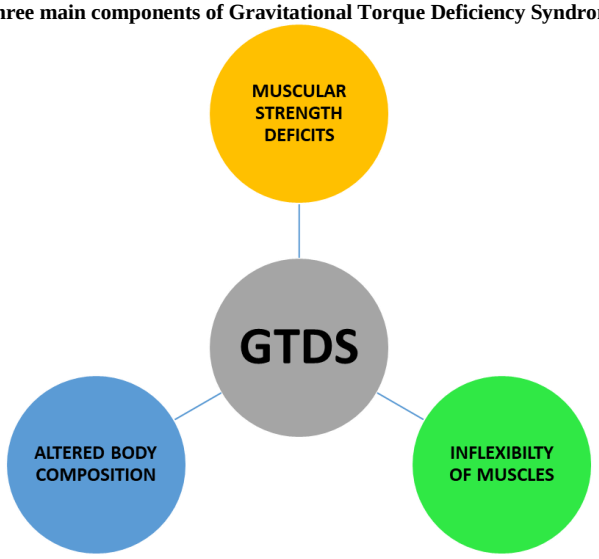

Table 1: Biomechanical hallmarks associated with ABCD and premature unhealthy aging.

Inability to do full depth lunge and squat with properly aligned torso.
Inability to activate Erector Spinae, thus, cannot avoid kyphotic vertebral column during forward bending.
Adapts to only walking, usually associated with excessive outward deviation of feet. Activities like stair climbing and running become very difficult.
Applies incorrect postural strategies to get up from the floor (supine lying or prone lying or side lying) to standing, almost resembling Gower's sign.
Proprioceptive deficits (especially in Single Leg Balance tasks).
Cannot jump or excessive hesitation to jump (vertical jump, standing long jump).
Below-average Push and pull strength of the upper limbs, and inadequate grip strength.
Several tightened muscles leading to aberrant joint mechanics and restricted mobility. Some individuals might display excessive vertebral column inflexibility almost similar to ankylosing spondylitis.
Inability to provide stable working foundation from the vertebral column (impairments in generating H_2I effect; Hoop tension, Hydraulic Amplifier and Intra-abdominal pressure) for the upper limbs and lower limbs, thus, various functional tasks or exercise postures would be accompanied by excess lordosis or kyphosis.
Lateral shuttle, Zig Zag Shuttle become less agile or more erroneous.

Conditions like GTDS is capable of affecting all the humans and its associated biomechanical dysfunctions (due to ABCD) usually remain asymptomatic for several months or even years. Till the end of life, humans should sufficiently expose their neuromusculoskeletal system to gravitational force to avoid losing athleticism, survival competence, homeostatic stability and healthy ageing trajectory. Many important variables should to be interlinked to identify the factors that can minimize ABCD or aggravate ABCD (Table 2, Table 3 and Table 4).

Table 2: In any similar age group, it is possible to find individuals of similar body weight but with different body compositions [Fat Mass - FM, Fat Free Mass - FFM], somatotypes and functional capabilities. As the fat% increases, athleticism or fitness excellence decreases. Scientific endeavours in the future should target identifying this diversity in all age groups to scrutinize if this hypothetical classification based on 'Ability to counteract gravitational force' is viable.

BODY MASS [80 KG]	**ABILITY TO COUNTERACT GRAVITY**
48 Kg FFM + 32 Kg FM [40% FAT]	Non-athleticism
56 Kg FFM + 24 Kg FM [30 % FAT]	Borderline athleticism
64 Kg FFM + 16 Kg FM [20% FAT]	Average athleticism
72 Kg FFM + 8 Kg FM [10% FAT]	Above-average athleticism

Table 3: Similar age group women with different body compositions, somatotypes and functional capabilities. Body Mass Index of Female A = 19.3 and Female B = 24.3. A knowledge about Heath-Carter Anthropometric Somatotyping is essential while doing such scientific comparisons and health care researches. It is very obvious from this data that Female A experiences premature aging (unhealthy aging) in association with below-average muscularity, muscular tightness and excess fat% for her body weight. Female B, though looks like better than Female A, also should try minimizing fat%, improve flexibility, and enhance muscular strength and endurance through appropriate lifestyle.

	Female A (39 years)	**Female B (39 years)**
Weight	57 Kg	73 Kg
Height	172 cm	174 cm
Fat %	35%	34%
Somatotype	Ectomorphic Endomorph 9.6: 1.4: 4.1	Mesomorphic Endomorph 9.8: 3: 2
Grip strength	Right hand: 28 Kg Left hand: 28 Kg	Right hand: 40 Kg Left hand: 35 Kg
Sit and Reach flexibility	- 29 cm	- 5 cm
500 meters Endurance Rowing in the machine at Resistance level - 10 (Maximum pace to reach the target distance)	6.8 Km/h	12.8 Km/h

Table 4: In different age groups also, it is possible to find individuals of similar body weight but different body compositions, somatotypes and functional capabilities. Body Mass Index of Male A = 25.7, Male B = 25.7 and Male C = 24.5.

	Male A (38 years)	**Male B (53 years)**	**Male C (53 years)**
Weight	70 Kg	70 Kg	69 Kg
Height	165 cm	165 cm	168 cm
Fat %	32%	35%	28%
Somatotype	Mesomorphic Endomorph 8.9: 4.5: 0.9	Mesomorphic Endomorph 10: 4.9: 1	Mesomorphic Endomorph 7.6: 3.4: 1.4
Grip strength	Right hand: 83 Kg Left hand: 62 Kg	Right hand: 43 Kg Left hand: 45 Kg	Right hand: 55 Kg Left hand: 68 Kg
Sit and Reach flexibility	- 10 cm	- 7 cm	+ 10 cm
500 meters Endurance Rowing in the machine at Resistance level - 10 (Maximum pace to reach the target distance)	14.4 Km/h	13.3 Km/h	13.8 Km/h

Medical profession is not completely devoid of pseudoscientific roots because prophylactic and therapeutic approaches have been deeply complicated without basically researching or learning about the homeostatic conditions of healthy individual. Assessments based on Body Mass Index and Master Health Check-up alone cannot completely reveal the fitness excellence and homeostatic excellence of an individual. It is not very complicated to understand the basic differences between healthy and unhealthy individuals (Table 5).

Table 5: Three primary differences between unhealthy and healthy individuals are simple to understand by evaluating their exercise performance. If statistical averages and benchmarks of health-related variables are derived from healthy individuals, then how the unhealthy individuals could be able to attain those health standards only through pharmacological approach? Healthy aging should be predominantly channelized through non-pharmacological strategies

	UNHEALTHY INDIVIDUALS (Foundations of homeostatic instability and unsuccessful aging)	**HEALTHY INDIVIDUALS (Foundations of homeostatic stability and successful aging)**
1	Less work capacity in a given time period	More work capacity in a given time period
2	Low resistance to fatigue	High resistance to fatigue
3	Slower recovery from fatigue	Quicker recovery from fatigue

DISCUSSION

"The aging of the population will undoubtedly result in higher levels of physical and cognitive disabilities that result from the aging process and chronic disease conditions that plague older adults. There is wealth of evidence that mobility function is closely linked to cardiovascular and muscular fitness, and, therefore, exercise can have important role in prevention and treatment of mobility impairments despite underlying comorbidities. Long-term behavioral interventions to combat mobility impairments originating from a wide variety of conditions have yet to be rigorously tested in clinical trials".[18] "It is often claimed that disability is bad for disabled people only when they live in an ableist social environment. But the disadvantages involved in disability and old age are bad independently of the nature of the relevant social environment in which they exist".[19] "Frailty is theoretically defined as a clinically recognizable state of increased vulnerability resulting from aging-associated decline in reserve and function across multiple physiologic systems such that the ability to cope with every day or acute stressors is compromised".[20] Although aging is a conserved phenomenon across evolutionary distant species, aspects of the aging process have been found to differ between males and females of the same species.[21] "Many age-

related diseases show sex-specific patterns. There is substantial individual variability in the aging process between men and women. In general, women live longer than men but women are frailer and have worse health at the end of the life, while men still perform better in physical function examinations".[22] "Compression of morbidity," of James Fries holds that if the age at the onset of the first chronic infirmity can be postponed more rapidly than the age of death, then the lifetime illness burden may be compressed into a shorter period of time nearer to the age of death.[23] "Polypharmacy is an area of concern for elderly because elderly people are at a greater risk for adverse drug reactions (ADRs) because of the metabolic changes and reduced drug clearance associated with ageing; this risk is furthermore exacerbated by increasing the number of drugs used. Prescribing cascade is said when signs and symptoms (multiple and nonspecific) of an ADR is misinterpreted as a disease and a new treatment/drug therapy is further added to the earlier prescribed treatment to treat the condition. This inherits the potential to develop further more side-effects and thus making a prescribing cascade".[24] Establishing non-pharmacological interventions that promote the adoption of a healthy lifestyle from early on could benefit older people to increase the number of years spent in a good health.[25] "Three patterns of healthy ageing trajectories were identified: 'high stable', 'low stable' and 'rapid decline'. People with multimorbidity displayed worse healthy ageing trajectories than those without multimorbidity or relatively healthy. With multimorbidity it was still possible to achieve health ageing. Instead of regarding older people as frail and potential burdens of public health, policy makers and practitioners should actively promote healthy ageing in the recognition that ageing is not synonymous with ill health".[26] "The capacity for human exercise performance can be enhanced with prolonged exercise training, whether it is endurance or strength-based. Endurance and strength training adaptations not only contribute toward sporting excellence but also toward the delayed onset of age-related diseases".[27] "Physical Fitness is an integrated measurement of all the functions (musculoskeletal, cardiorespiratory, circulatory, metabolic and neurological) and structures involved in performing Physical Activity. Improving Physical Fitness should be considered as a primary objective in promoting public health".[28] "Individual-specific exercise prescriptions are always a daunting challenge, especially for the individuals (regardless of their age) who are traveling along the unhealthy ageing trajectory associated with many symptomatic and asymptomatic dysfunctions/morbidities of the body. Exercise tolerance or intolerance can objectively reveal individual-specific homeostasis, healthy stability/instability, and healthy or unhealthy ageing trajectory. A single objective measure of homeostasis based on exercise tolerance will suffice to understand a person's immunocompetence, resistance to diseases, prospective ageing trajectory, recovery from any illness, etc.,"[29] "Faulty postures and movements could lead to subluxation of joints, which might even remain asymptomatic or unnoticed for a long period of time. Stretching exercise is the most indispensable efficacious exercises to preserve perfect joint axis, and if meticulously performed, could contribute to improved exercise performance. Maintenance of full range of motion of all the moveable axial and appendicular joints ensures adequate exposure of the neuromusculoskeletal system to gravitational forces, and help preventing the debilitating effects of Gravitational Torque Deficiency Syndrome".[30] "Like a number of geriatricians, I have come to believe that modern medicine does not work well for old people. Old patients serve as a mirror, reflecting the limitations and sometimes the absurdities of modern medicine. There are three areas that are particularly problematic for old people: the medicalization of everyday life, the primacy of diagnosis, and

reimbursement for medical care".[31] Biomechanical hallmarks of unhealthy aging have been concisely outlined in this article but in reality, they are responsible for excruciating unsuccessful aging. It is clearly evident that a highly specialized domain that merges biomechanics with gerontology becomes vital.

CONCLUSION

Various reversible and irreversible biomechanical dysfunctions serve as hallmarks of unhealthy aging and premature unhealthy aging. These geronto-biomechanical dysfunctions are the visible roots of unsuccessful aging from which any age-related disease may originate. All types of muscle work (Concentric contraction, Eccentric contraction, Co-contraction, Isometric contraction, Synergistic contraction) get affected with unhealthy aging whilst active individuals, whose occupation naturally demands diverse functional tasks, might continue maintaining key biomechanical foundations necessary for healthy aging and longevity. Uncontrollable tendencies to opt faulty longer leverage mechanisms when actually short leverage mechanisms needed, and uncontrollable tendencies to opt faulty shorter leverage mechanisms when actually longer leverage mechanisms needed, are important mechanically inefficient movement patterns associated with unhealthy aging, and needless to say, faulty movements could lead to irreparable injuries. Even arm-dependent locomotion become defective due to unhealthy aging; hence, assessments and exercise variations of the healthy aging programs should also prudently incorporate quadrupedal postures. Impairments in generating H_2I effect (Hoop tension, Hydraulic Amplifier and Intra-abdominal pressure) could diminish core stability, thereby the functional outputs from upper and lower limbs also get affected. Complete exposure of neuromusculoskeletal system to gravitational force in both open kinetic chain and closed kinetic chain on a regular basis is the essential prophylaxis to promote or ensure healthy aging. "Not all the movements become exercise, and Not all the exercises require movement", therefore exercise prescriptions should possess sound biomechanical and objective rationale to exclude illogical exercise variations. In combination with fat percentage testing, periodic Heath Carter Anthropometric Somatotype assessments could help revealing the altered body composition precisely, to investigate and comprehend the individual-specific aging trajectory. Through visual observations and objective physical efficiency tests, it is possible to build a vast repertoire with nomenclatures pertaining geronto-biomechanical dysfunctions and classification systems for aging trajectory as a distinct curriculum in gerontology.

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