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Optimization of the Application Software in Biomechanics and Their Contribution to The Biological Field

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Abstract

Biomechanics refers to study of movement within dynamic biological systems. Advancement of computer software technologies such as JAVA language leads to combine stimuli and signals by biological systems and utilize them for research purposes. The main aim of this research is to analyse various biomechanical software and advancements that have been made in the field of mechanical software. Secondary research analysis has been utilized within this research paper. A Number of computational software such as OpenSim and ABAQUS have been proven to be very beneficial in this aspect. Advancement in biomechanical software has led to better research in cancer and cytoskeletal studies. Thus, Biomechanical software enables us to study kinetics of body without invasive procedures and does not cause any hindrance to ethical issues.

Keywords: Biomechanics, software technologies, OpenSim, simulation models, kinematics, cancer, cytoskeletal structures, muscles, skeletal system

1. Introduction

Every biological structure is subjected to gravity. The form and mechanics of motions are directly and indirectly affected by gravity. The study of such biomechanical and dynamic systems has been into practice since centuries. Various researchers have strived to understand underlying principles and mechanisms of physical bodies when they are subject to displacement or force. Since the advent of technology and computers several numerous researches has been initiated to combine mathematical and physical principles in order to understand proper functioning of dynamic biological structures. Many of the advanced technologies such as real time imaging, high definition and motion sensor cameras has been utilized to create a simulated biological models in order to properly understand their response to force and inertia. The study of dynamics are not only limited to bones and muscles. They have been extended up to cellular and sub cellular structures. This helps in creating treatment protocols and leads to better understanding of underlying mechanisms of several diseases.

The main aim of the research is to analyse various biomechanical software and advancements that have been made in the field of mechanical software. In addition, the contributions of several software in field of biology has been analysed within the research paper. The main objective of current research is to identify certain software that is used in biomechanical studies of dynamic biological systems. The research paper analysis the development that have occurred within biomechanical software and the ways they have found applicability in assisting patients suffering from movement disorders.

Advancement of computer software technologies such as JAVA languages lead to combine stimuli and signals by biological systems and transform them into electronic signals. The use of computer applications has been immensely utilized in field of biomechanics. Highly developed kinetic sensors are used to detect minute movements made within muscles and then present it in analogue signals for computer software to utilize. Moreover, computer software has been effectively developed to create simulation models. This leads to better understanding of mechanics of skeletal and muscular systems. In addition, injuries and their possible impact on human bodies are easily analysed without usage of real life subjects.

One of the most notable advancements that have been made in biomechanical software is imaging and real time motion capture of cytoskeletal structures. In addition, biomechanics have been proved to be useful in neurological domain. Various phenomena such as neuronal migrations and degradations can be effectively captured and their progress can be monitored by utilizing software such as Zen software.

Biomechanical software enables proper evaluation and provides better understanding regarding kinetics and mechanics of dynamic biological systems. In addition, various complications in movements and cytoskeletal functions are shed light by application of biomechanical software. In addition, precision and specific observation of various joints and muscles of body can be effectively evaluated. At the end of the research paper a well evaluation and identification of several software that are currently

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deployed for analysis of mechanics of biological system has been established. In addition, the progress that has been made in the field of biomechanics and the ways researchers have been benefitted from them has been analysed in the current research paper.

2. Literature Review

2.1 Need of software in Biomechanical studies

Biomechanics is concerned with the movement of biological systems. The study encapsulates the ways in which biological systems and structures respond to various forces and external stimuli. Biomechanical studies provide a proper outlook regarding dynamism of muscular and skeletal systems [1]. Biomechanics proves to be suitable amalgamation of physics and mathematics regarding functioning of dynamic biological systems. Biomechanics has been utilized and researched upon since the advent of humanity, however in the recent years technological advancements have made the study more prompt and effective. Since Biomechanics is concerned with the study of skeletal system, manual study of dynamic study poses to be problem. Simulation of dynamic systems such as various muscles and bones makes study of their movements and dynamics feasible [2].

Another arena where software simulations programs are inevitable is studies relating bone and muscular injury. Software such as OpenSim proves to provide exemplary assistance regarding studies of bone injury within athletes and military service men [3]. This software has been effectively used for creating simulation for designing and testing suits for soldiers. Moreover, biomechanical simulation software is required for analysis of fractures and other osteological complications. Development of motion capture and VFX systems have led to analysis of injuries that are often incurred within sports personnel. The range of motions and momentum calculations can be effectively using simulation programs.

Biomechanical software also finds its application regarding dynamic behaviour of cytoskeletal movements. Several cytoskeletal disorders such as Achondrogenesis, caused due to defects in microtubules of Golgi apparatus can be effectively screened using biomechanical simulation software [1].

2.2. Critical analysis of current software in biomechanics

Biomechanics is not only limited to osteological and cytoskeletal studies. A novel biomechanical device named GoldFinger provides to be efficient wireless human machine interface and is provided with dedicated software and energy harvesting systems. The main aim of development of such electromechanical devices is to sense motion and posture thereby converting them to electronic information in form of C++ language [4]. Another frontier that has been made in this software is storing and conversion of kinetic energies. Several human computer interface are created that can store kinetic energies of the body and them convert them into mechanical energy.

Static equilibrium	$\sum F = 0, \sum M = 0$
Dynamic equilibrium (equation of motion)	$\sum F = ma\,, \sum M = Ia$
Work done by a constant force	W=Fx
Work done by a varying force	$\int_{x1}^{x2} Fx\,dx$

Fig. 1. Figure for the mucoskeletal dynamic equation

The figure 1 illustrates the equation that is used for the calculation of the biomechanical motion of the musculoskeletal muscles. The equation describes the calculation of the scalar units of force and momentum [5]. In the recent years, the use of piezoelectric and optical fibres has been increased immensely and subsequently, stimuli received by sensors can be effectively utilized by computer software [6]. This advancement has led to better physiotherapeutic outcomes and provides assistance to many individuals living with disabilities.

2.3. Advancement made in field of biomechanics

In the modern era, human motion analysis and their study had developed rapidly owing to increased knowledge of anatomy and mechanics. Notable advancements in the field of technical biomechanics were evident with development of high speed stroboscopic photography that was developed by Harold Edgerton in 1940 [7]. It used the basic principle of photography at a frequency of several millions every second. The development of video camera systems along with infrared high speed cameras in the late 1970 lead to perfect amalgamation of utilizing software technology along with visual data. It was only till late 1980 that super computer software were applied along with high definition motion sensor cameras were used with the objective of creating three dimensional human models and to simulate human movements within software [8].

Notable development in fields of biomechanics was seen with studies conducted by Verne Thompson Inman with the aim of studying movement disorders among gait patients [9]. However, the time consuming nature of processing and analysing cine films had proved to be hurdle in prompt analysis of human motion studies. The development of 3D Vicon motion captures system lead to collect human motion data in forms of numeric data instead of analogue data [4]. This is due to fact that numeric data are easily analysed by computer software and inference can be drawn. Another major advancement that has been made on the field of biomechanics is the utilisation of sound track along with 16mm movie camera for analysing phasic action of muscles. This technique is widely used for analysing muscular functionality within patients of poliomyelitis. In the present decade, some of the most commonly biomechanical simulation software includes OpenSim, Zen software and Ansys [10]. Zen software is a powerful application that utilizes AxioCam microscope in order to picture cellular structures and capture movements of cytoskeletal systems such as microtubules and microfilaments.

2.4. Role of sharing model and related resources in Computational biomechanical software

The use of computational modeling in biomechanics researchers have proven to be very beneficial by the fact that numerical data are generated from biological stimuli and subsequently computational analysis can be made. The association between biomechanics and computational modeling are increasingly utilized in order to explore and understand the mechanics and mechanobiology of various diversified biological systems [11]. Computational modeling

has been proved to be boon for creating simulator models for bone fractures and skeletal problems. This leads to proper and correct calculation of data regarding kinetics of muscles. In recent years, models have also been created for understanding the pathophysiology and etiology of several diseases such as osteoarthritis, cardiovascular and cerebrovascular aneurysms.

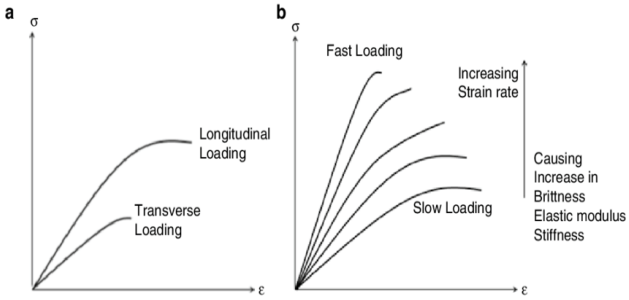

Fig. 2. Figure for the stress strain curve for bone

The figure 2 (a) depicts the direction dependent stress and strain curve for the bones. The ultimate stress that is applied is termed as the σ and is determined by the longitudinal and the transverse stress that is applied on the bones. The figure 2 (b) depicts the fact that with an increase strain and stress on the bones the brittleness of the bones increases due to the stiffness of the bones. Use of simulation based designing computational software has been widely used form rehabilitation therapies to that of designing of cardiovascular stents [9]. In addition, in-silico medicinal approaches and designing of orthopedic implants have obtained great advantage by the application of computer based modeling of human architecture. Computational modeling software has significantly used use of human and animal models [12]. Many of the outdated and complicated processes such as cadaver testing and researchers on animals have been prohibited within many studies and researches. Computational biomechanics related primarily on visual representation of anatomical, physical and physiological properties of biological structures. Application of simulation software in recent decade is not confined to muscular and skeletal systems. The horizons have expanded up to cardiovascular, neural up to cellular and molecular levels of biological systems [13].

2.5. Unambiguity among biomechanical software

One of the primary reasons that computational modeling and simulation software proved to be effective in studying underlying mechanism of biomechanics is that it is easily reproducible. The simulation software can be used upon any human system and is not limited to specific conditions. A model simulation of human systems produces identical results on reported experimentation and requirements of such software are negligible [12]. The results produced are unambiguous and combines specific value of model equations, various parameters and boundary conditions. In this context, markup languages such as CellML, NeuroML and FieldML prove to be of exemplary assistance and are widely used by researchers of biomechanics across the globe [14]. Modeling software such as MATLAB Figure Viewer has led to creation of virtual human structures and enabled better study of accident related injuries. Another advantage of computational software is calculations and analysis of huge number of data can be made in as meticulous manner. Accuracy and scope of biases within results are effectively reduced and results can be producers in a proper manner [3].

2.6. Development of motion analysis software

Biomechanical researches effectively use existing and novel methodology in order to provide better simulation of biological systems in motion. X-Ray reconstruction of Moving Morphology is one of the advancement in biomechanical software that utilizes static bone shape data from CT scan along with motion data that are obtained from X-ray videos. XROMM software are not only limited for studying motion within human systems [15]. They have been applied to study morphological and mechanical movements within reptiles, fishes and even arthropods. One of the most notable utilization of XROMM software is motional activities of even extinct animals can be evaluated. Such software has been used to analyze track way formation in theropod dinosaurs. Since 2001, marker based XROMM has been extensively used that utilizes radio-opaque markers being surgically implanted within skeletal elements [16]. Such techniques provide clear image of bones and muscles within their natural environment and any discrepancies within their normal functionality can be outlined [17].

Marker based XROMM requires additional software that are required for correction of distortions created by fluoroscopic image intensifier and calibrating cameras [15]. In addition, tracking of radio markers and calculation of rigid body motion poses to be problematic for the researchers. In order to mitigate this shortcoming, a novel motion sensor software namely XMALab has been introduced in the year 2015 [18].

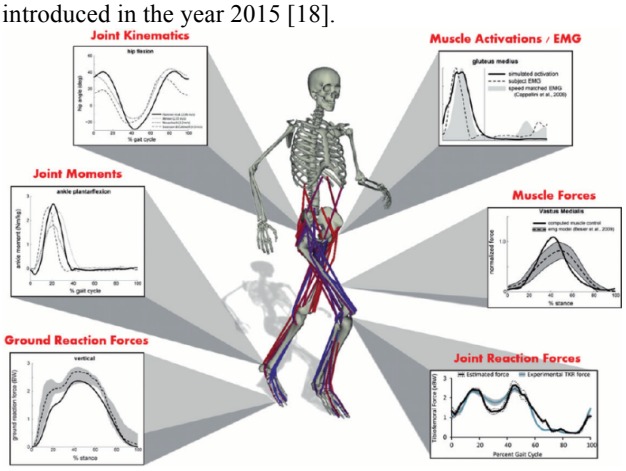

Fig. 3. Figure for simulation models in biomechanics

The figure 3 depicts the simulation model for the biomechanical movement modeling. It involves the calculation of the joint kinematics and the joint-joint interaction forces [19].

The main advantage of XMALab is that it is user friendly and helps in highlighting all the errors that are incurred during data processing. In addition, a clear visual feedback is given to users further removing any introduction of errors while generating results. The main purpose of creation of user friendly biomechanical software is that many of the biologists do not have expertise regarding data processing and system software [20]. In presence of complex computational and motion studies prove to be a hurdle in proper utilization of features and subsequently fraudulent data might be produced. It is evident with progression of time that more focus has been put on creation of user friendly software that simultaneously produces accurate and precise results.

3. Research Methods

Secondary research analysis has been utilized within the research paper. Data and facts pertaining to biomechanical software have been collected from several journals and articles. In addition, several online articles were collected for gaining information regarding developments that have been made in software for understanding principles of biomechanics [21]. Thematic analysis has been utilized within the research paper [22]. The data collected by scrutiny of several journals were used to create various themes and based upon them results were deduced. Moreover, thematic analysis method provided a definite direction to the research and results were derived. [Refer to Appendix 1]

Several databases were searched for obtaining relevant literatures related to bio-mechanical software. Some of the databases that were searched include PubMed, NCBI and Ovid. The search for relevant literatures was made using the keywords mentioned in the previous sections. On using the keywords, a total of around 1125 journals were obtained. The journals that was older than 2014 were excluded. Accordingly themes were created as per the obtained journals and their relevance. As qualitative research methodology is utilized for the research, thematic analysis was implemented. Thematic analysis is one of the clustering methods that help in identifying a pattern of results while searching for relevant literatures within the databases. Thematic analysis is important for this research as answers to research questions are obtained through rigorous process of data familiarization. Subsequently data coding, theme development and revision are carried out for obtained desired results [13]. It proved to be beneficial as it is a time saving and flexible approach. A broader pattern regarding advancement made in the field of biomechanics software has been obtained and narrative analysis conducted. This approach helped in the process of research in order to shifting analysis from a wide array of data to discovering patterns and development of themes.

Deductive thematic analysis has been used within the research [23]. A predetermined structure and themes that was created with axial coding was used to analyze the data and facts that were obtained following scrutiny of relevant literatures [1]. As themes were generated previously by researchers, the similarities and differences within results and facts could easily be deciphered. [Refer to Appendix 2]

4. Results

4.1. Application software for creation of simulator models

The recent advancement in the field of biomechanics has led to creation of several simulator models. Subsequently, the anatomical and physiological features of human body can be understood effectively. Software such as OpenSim lead to virtual pixilated structure of human body and all the mechanics are effectively studied. Such software is widely used in sports and military services. Another application of simulation model is analysis of injuries and accidents are established [10]. The use of simulation models are not only limited to movement of dynamic systems. They have also been used to understand and analysis composition of various body parts. The materialistic properties of bones can be effectively evaluated through software such as ABAQUS. Application of this software leads to creation of finite element mesh structure of bone [4]. The researches in creation of simulation models have improved significantly. A scrutiny of various literatures suggests that researches for creation of application movement software have been increasingly improved over the years. Certain software such as Bonemat posed difficulty for researchers as it is compatible on Windows platforms [24]. In this context, ABAQUS is compatible on several platforms as it is written in Python language.

OpenSim is an open multi-platform source, multi-user 3D application server [25]. It can be used to create a virtual environment which can be accessed through a variety of clients, on multiple protocols. It also has an optional facility (the Hypergrid) to allow users to visit other OpenSim installations across the web from their 'home' OpenSim installation. In this way, it is the basis of a nascent distributed Metaverse. Abaqus FEA is a software suite for finite element analysis and computer-aided engineering

4.2. Software in cancer studies

The use of biomechanical studies has been proved to be very useful for studying cancer among human subjects. The movements and kinetics of genes and underlying mechanism of mutations can be effectively studies using microscopic imaging.One of the common pathophysiology that is of great concern among researchers is metastasis that leads to spread and permanent location of cancerous cells within various regions of the body [11] . The levels of dynamics among cancer cells increase up to huge manifolds and this peculiar feature has been used to create biomechanical models. Software such as canopy has led to analyze movements of cancerous cells using biomarkers. It is open source software that leads to tracking of cells and bringing out genotypic differences among cells [26]. In addition, advancement in the technology of breast cancer treatment has led to tracking of HeLa genes and understanding their mechanism of metastasis.

The dynamics of cell movement are effectively analyzed by microscopic tracker software such as Zen software [4]. The use of AxioCam cameras lead to create pictures of cellular components and lead to analyze and structural differences that might be created due to cancer. Such mechanical software brings out any anatomical structures having resulted from mutations and subsequently progress of cancer is analyzed.

4.3. Utility in defense and sports physiology studies

Biomechanical software is greatly utilized in the fields of defense researches. Stimulatory models are used for creation of ergonomic suits for defense personnel. OpenSim is extensively used for analyzing the pressure that is put on military men by their heavy arms and backpacks. The deleterious effects of additional weights are effective calculated and subsequently improvements are made. Moreover, effects of rough terrain on movements are analyzed [27]. The effects of injuries and musculoskeletal disorders are effectively treated with biomechanical software. Along with imaging techniques such as CT Scans and MRI, any injuries and faults within the musculoskeletal system are effectively outlined by number of software [28].

Sports personnel and trainers have been greatly benefitted from number of mechanical software. The intricacies, complexities and speed of sports require accurate and robust mechanical software [29]. Motion capture systems are widely utilized in various aspects of sports

physiology in order to improve performance of sportsmen. In addition, technologies such as Raptor-12HS and Kestrel provide real time imaging and motion analysis in order to prevent injuries sustained during several sports events. Stimulatory programs have also enabled trainers to seek out and improvise new techniques within several spheres of sports [14].

4.4. Utilization in cytoskeletal studies

Dynamism within intracellular structures is effectively screened using biomechanical software. Software such as MATLAB help in calculations and analysis of data limited within microns. The movement and functioning of cytoskeletal elements such as microfilaments are effectively picturized using microscopic photography techniques such as Zen software [6], [30]. These advancements have led to opening of new horizons regarding cytoskeletal disorders such as Achondrogenesis. In addition, mechanism of cell division and the role of microfilaments in such processes are put into focus [15].

5. Linking Of The Research Results With The Research Aim

5.1. Development of meticulous calculation and motion sensors software

Application of calculation software in biomechanics

Biomechanical recordings comprises of specific and precise recording obtained from slightest movement of muscles. Such data are difficult to calculate and their analysis and interpretation requires proficient software. MATLAB is one of the high performance language software used for technical computing of large number of data [31]. The solutions are expressed in familiar mathematical software and are compatible with Windows, macOS and Linux operating software [7]. In addition, huge number of data can be calculated in an error free manner.

Motion sensor and high definition camera in field of biomechanics

Optical motion capture cameras enable to form three dimensional positions of different limbs and body parts. The development and advancement of such kind of technology has enabled non-intrusive and lightweight biomarkers within animal models [32]. This enables in obtaining accurate motion models without causing hindrance in normal movement patterns in measurement situation. Software such as KinToolsRt provides complete analysis on kinetics and kinematics regarding motion sensor requirements [10].

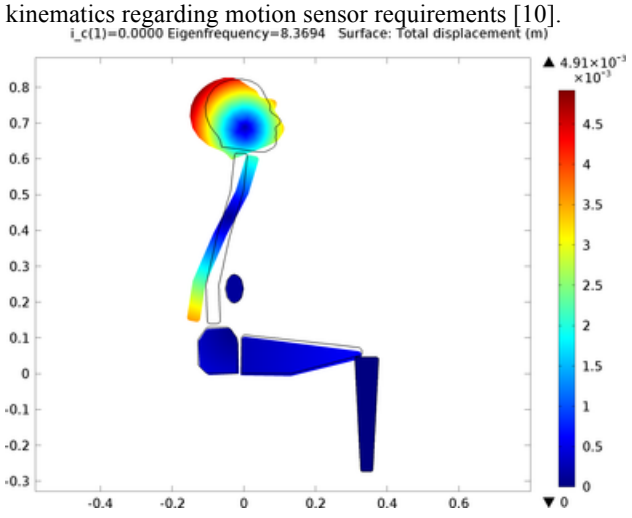

Fig. 4. Figure for biomechanical model of human body

The figure 4 depicts the dynamism of the human body during body movement. This involves the simulation of the body posture and the Multibody Dynamics interface. In addition it allows the analysis of the response of the muscles to the vibrations [33].

Utilization of this software enables researchers to create custom models and perform a range of motion along with meticulous calculations. In addition, certain software can obtain visual representation of magnitudes of calculations comprising of joint movements and angles from skeleton itself. Moreover, dynamics and range of motion of joints can be easily visualized [4]. This helps in finding possible reasons and pathophysiology of fractures.

5.2. Applicability of Biomechanical software in various fields

In sports and exercise physiology

The applications of biomechanical software are of great extent in the field of sports and exercise physiology. It is due to the fact that studies of movements pose many difficulty using human and animal models [14]. In addition, the reproducibility of the results is very limited using real life models. Ethical issues and risks associated with invasive procedures put great limitation. With the advancement of motion sensor technologies and high definition cameras, the studies regarding kinetics and kinematics of joints have been improved significantly [1]. Moreover, the development of 3D Vicon motion capture systems has led to easy calculation of obtained data as numeric data instead of analogue data are being input into computer system [24].

The combined use of sound track along with motion sensor system proves to be beneficial by the fact that minute changes in movements of bones and joints can be measured. Utilization of such technologies has led to improvement of performances among athletes and other sports personnel [34]. Moreover, various forms of exercises and training exercises are designed based upon movements and requirements of sports activities. Physiotherapist and sports researchers can have deep insight knowledge regarding movement of muscle joints and do not have to depend upon myographic recordings for analyzing their movements [29].

Cancer and cytoskeletal studies

The dynamics of cellular and sub cellular components of biological systems have been effectively evaluated using software such as Zen software [3], [30]. Picturization and possible location of cytoskeletal structures such as microfilaments can be easily identified and evaluated. Such advancements have led to better understanding of cytoskeletal structures within cells and dynamics of movement of molecules within cells. Biomechanical software has led to better understanding regarding metastatic nature of cancerous cells [35]. The movement of cancerous cells from tumour sites to normal site within human body has led to better analysis and screening cancerous cells [18]. In addition, such technologies are also useful as majority of them utilized noninvasive methods and neutral biomarkers without causing much pain in patients. It enables maintenance of ethical issues among patients [14]. Moreover, false positive data can be prevented. Such technologies also find its applicability within future treatment protocols of cancer and development of drug.

Moreover, researchers regarding cancer and cytoskeletal disorders can be effectively studied within simulated environment. This prevents disruption of normal physiological functioning and ethical considerations are maintained [1].

6. Conclusion

It can be concluded that utilization of advanced software has led to notable and wide improvement in the field of biomechanics. It has led to creation of human and animal models within simulated conditions. The requirement of animal models and invasive procedures has been reduced to a great extent. The results that are produced using mechanical software are easily reproducible and validity is ensured. The risks of errors and biases in the results are also minimized. The use of motion sensor cameras has enabled to track and capture minute movements in muscles. This has been proved to be beneficial for analysis of movements and subsequently treatment for musculoskeletal disorders can be evaluated [36]. Another major application of biomechanical software has been in the field of sports and defense research. Various ergonomically feasible suits and equipment are created using data received by several biomechanical software. Moreover, biomechanical software has contributed significantly in the field of cancer therapy. The nature of metastatic tumors and dislocation of cancerous cells are evaluated effectively using noninvasive and safe biomarkers. The future implications of such software seem to be very promising for several patients suffering from musculoskeletal disorders and even cancer patients. In addition, the efficiency of sports personnel can be improved by better understanding of anatomical features. Real time imaging and simulation software enables researchers regarding kinetics of biological systems to be conducted in a systematic manner. Thus, it is undeniable fact that advancement in the field of mechanical software has been noteworthy. This has proven to be of great boon in various biological fields and the ongoing progress promises of bright future.

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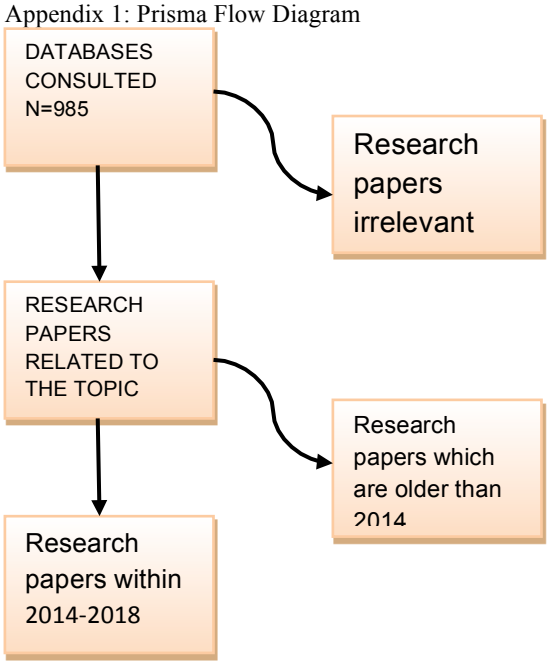
Appendix 1: Prisma Flow Diagram



Appendix 2: Axial Coding

Sr. No	Axial Coding	Verbatim
1.	Biomechanics	Biomechanics leads to proper understanding of dynamics of biological structures under influence of force and motion
2.	Software technologies	Technologies such as OpenSim helps in better understanding of biomechanics
3.	Simulations models	Simulations models creates models of human structures for better understanding of their movement and dynamics
4.	Cytoskeletal structures	Biomechanical software leads to understanding of dynamics regarding cytoskeletal structures