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Article

Hip joint motion amplitude control based on exponential product formula

Jiexiu Yin[1], Zhaohui Qu[1], Juan Li[2,*], Yan Li[2,3], Xiaoyuan Zhang[3,4]

[1] Department of Physical Education, Taiyuan Institute of Technology, Taiyuan 030000, Shanxi, China
[2] Physical Education Institute, Lianyungang Normal College, Lianyungang 222000, China
[3] Suzhou Vocational University, Suzhou 215104, Jiangsu, China
[4] Lianyungang Sports School, Lianyungang 222000, China
*** Corresponding author:** Juan Li, lygsztylj@126.com

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Abstract: Background: Handball is a team sport, and during a game, there is a lot of direct squabbling and close contact between the players. **Objective:** The goal of the research is to determine how handball training affected several aspects of physical fitness. The study also investigates the relationship between playing handball, passive hip range of motion (ROM), and the development of radiologically detectable hip osteoarthritis (OA) in formerly elite handball players. The research employed the exponential product algorithm for evaluating bilateral radiographs to classify and diagnose hip OA. This technique most likely evaluated subchondral sclerosis, osteophyte formation, joint space narrowing, and other radiological signs of OA in the individuals' hip joints. **Methods:** The relationship among the risk of hip OA in long-term top handball players is explored, as well as the connections among hip ROM, OA, and pain. The research was conducted using a sample size of 20 ex-professional handball players and 39 control subjects. Information on demographics, loading patterns during exercise, and history of lower limb joint injury were gathered via a questionnaire. The inclusion criteria for individuals consisted former professional handball players with significant elite-level competitive experience, as well as control subjects with no background of high-impact sports. Confounding characteristics such as age, gender, and previous lower limb joint injuries were carefully controlled for using extensive demographic and injury history evaluations. To identify and categorize hip OA, bilateral radiographs were analyzed using the exponential product algorithm. The goniometer was used to assess the bilateral passive hip ROM. Long-term participation in elite handball at a high level was found to have a strong correlation with the hip development of osteoarthritis (OA). Sixty percent of handball players had been identified with OA in at least one hip joint, compared to only thirteen percent of control patients. **Results:** Hip flexion and medial rotation in the handball players were significantly decreased, whereas abduction, extension, and lateral rotation were increased considerably compared to the control values. When doing daily activities, the hip joints of the handball players with OA were less painful than those of the OA-afflicted control participants. Retired handball players seem to be at a much higher risk than the general population for developing early hip OA. **Conclusion:** The repetitive nature of handball-specific movements may result in anomalies that are seldom seen in the general population, which makes diagnosing pain and discomfort a challenging diagnostic challenge for sports physicians.

Keywords: physical education; training; exponential formula; hip range of motion; osteoarthritis; elite handball

1. Introduction

Since the physiology and functioning of the lower back and lower limb are described in different frames with little information to link them, the treatment of the pelvic floor and lower limb muscle is planned and carried out independently. The obturator internus, sometimes referred to as the "hidden" muscle, belong to the lesser-known anatomical components among some of the lower limb muscles. Through its assistance in hip movement and abduction, the obturator internus is essential for handball players' hip stability and movement. Because of its deep pelvic placement, it helps to stabilize the hip joint, which is important for the rapid shifts in direction and quick movements needed for handball. For handball players, strengthening and correctly activating the obturator internus can improve agility and reduce injury risk. One of the hip's six inner medial rotator muscles, the obturator internus regulates the hip joint's outer rotation and extension. As most power is encased in the hip bone, it is hard to figure out its form outside the body. Several imaging techniques are used to examine the form and function of the hip bone in healthy individuals. X-rays produce precise images of bone structure but do not detect soft tissues. Although MRI takes longer and is less accessible, it provides better soft tissue detail. CT scans allow for the visibility of both soft tissues and bones, but they also exposing patients to ionizing radiation. Despite Improvements adequately measuring hip bone structure and function in vivo is still difficult due to limits in spatial resolution, exposure to radiation, and expense. The obturator internus is an exciting muscle because, although being a lower extremity muscle, it is also a part of the pelvic wall [1]. The obturator internus muscle, which is found inside the pelvis, is essential for movements of the lower limbs, especially the thigh. Its role is to rotate the thigh externally, despite being located in the pelvis. It is a unique and fascinating muscle in the body because of its dual function as a component of the pelvic wall and a lower extremity movement associate [2]. Motion analysis has uses in diagnosing, preventing injuries, evaluating rehabilitation, and characterizing gait. A 3D webcam laboratory system monitoring reflecting markings over anatomic structures on a subject is the most used technique for movement analysis. These systems, despite being well-established, are constrained by their high prices, lack of mobility, need for trained personnel, and probable marker occlusions. With a focus on tracking athletic populations and treatment plans, motion analysis outside of a lab has become more and more common. As a result, initiatives to apply ubiquitous motion analysis techniques are growing. Motion analysis outside of the lab would make it possible to understand human motion not only in the laboratory but also in natural environments. It provides us with data about a variety of activities, athletic performance and the state of rehabilitation, which now enables to develop optimal treatment and increase efficiency [3].

The position of the acetabulum and the Lewinnek safe zone has traditionally been used to describe and assess how well the OA hip joint functions. In this work, we assessed the acetabular component's placement following total hip arthroplasty (THA) using the Lewinnek safe zone. This zone designates a range of inclination angles (usually between 30 and 50 degrees) where the acetabular component is thought to be ideally placed to reduce the chance of dislocation. Improved stability and functional results after THA are the primary objective, especially for patients with osteoarthritis, by guaranteeing that the acetabular portion remains within this safe area. Our research evaluated the relationship between postoperative functional results, such as range of motion, pain reduction, and satisfaction among patients, and acetabular component location within the Lewinnek safe zone. Recent studies have emphasized how the spine-pelvis-hip complex works together as a synchronized functional system that enables changes in the body's postural alignment [4,5]. The spine-pelvis-hip system functions together to promote synchronized motion and preserve stable posture. The pelvis operates as a central anchor for mobility, while the spine offers structural assistance. The complex system of joints and muscles in the hips transfers pressures from the upper to the lower body, promoting balance and fluidity in movement. This study has led to the emergence of two schools of thinking. According to one group that examined the spine's anatomy, the spine is the starting point for function. The second group emphasizes the hip as the source of motion, emphasizing the hip's anatomy as more crucial for postural adjustments [6].

None of the existing therapies consider the mobility of the arms and shoulders during running, even though several prospective trials have shown encouraging pain reductions via hip rehabilitation and brainwave entrainment gait retraining. During running, the movement of the arms and shoulders impacts the posture and balance, which in turn impacts the hip joint's coordination along with the complete body. In addition to improving hip function and possibly lowering the risk of strain and injury, proper mobility minimizes compensatory motions. Just two merge studies that evaluated the running kinematics of male and female runners took upper body movement into account. Both of these researchers found that female runners had higher oscillations in pelvic and lumbar axial rotation [7]. Uncertainty exists about the connections between the movements of the hip and knee joints during in vivo landing. Moreover, it is uncertain which of the hip and knee joint movements and seconds have the most impact on the maximum knee joint excursions, such as abduction, range of motion, and flexion. Knowing about the connections between knee and hip joint movements and external joint points in time during a slide jump test may enhance jump-landing training and optimize hip joint motions, resulting in a reduction in the maximum knee victimization and inner angulation and an increase in the peak flexion angle [8]. **Figure 1** shows the flow chart of OA functions. It is believed that the major external hip rotation and extensor muscles play a significant part in preserving hip joint stability. In the presence of hip dysfunction, the functioning of these muscles may change, which may affect interpersonal and inter-loading and the healthiness of the joint tissue. Exploration of activities that demand mobility towards such a highly provoking, impinging posture is expected to further describe FAI-related neuromuscular changes since the deep hip external rotator and extensor muscles mechanically resist impingement. Squatting tests the lower limb's functionality, pushes the hips into impingement, and is usually advised after recovery from FAI condition surgery [9].

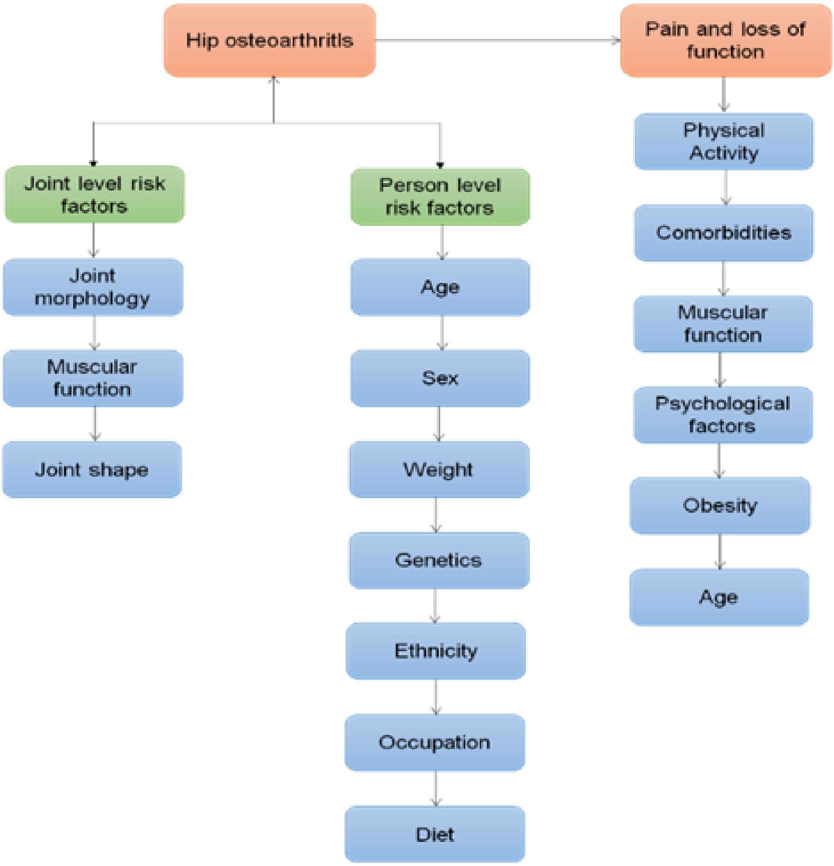

Figure 1. Flowchart of OA functionalities.

Impingement and dislocation remain significant factors in total hip replacement (THR) failure despite advancements in surgical methods and implant designs; this is because postoperatively, range of motion (ROM) while everyday activities are still restricted. Detachment is one of the most common adverse effects following a hip replacement, along with aseptic loosening. The most frequent reason for revision surgery is thought to be dislocation in the USA. For patients with excessive motions in various communities across the globe as well as for youthful and more energetic patients, a high ROM is crucial. In addition to bones and prosthesis impingement, the surrounding soft-tissue tissues may potentially restrict the range of motion (ROM) of THRs [10]. Femoroacetabular impingement (FAI) condition and labral tears seem to be the most typical causes of hip-related groin discomfort [11]. To diagnose FAI syndrome, a combination of symptoms, clinical indicators, and radiological evidence must be present. FAI syndrome symptoms include hip or groin discomfort that is triggered by movement or by position, with or without other signs, including clicking, catching, locking, and stiffness. Clinical indicators include restricted hip range of motion and the patient's normal discomfort being reproduced during hip impingement testing (ROM) [12]. Lastly, the radiographic findings include the femoral head having an oval shape (CAM morphology) or being covered by the acetabulum. After all other requirements have been satisfied, graphics intra-articular block injections may be utilized to further verify the diagnosis. It is still possible to reconstruct the hip; however, the long-term risk of osteoarthritis, as well as the likelihood of another dislocation occurring and the functional outcome, are unknown. The purpose of study is to evaluate the lengthy medical and imaging consequences of hip rebuilding by dega type pelvic osteosynthesis performed in patients with cerebral palsy after fusing the downtrodden epiphyseal cartilage in patients.

Research highlights:

- Players in a handball match often come into physical contact with one another and engage in open squabbling as a team sport.
- Finding out how different components of physical fitness were impacted by handball training is the main objective of the research.
- In addition, the study looks at how handball, passive hip ROM, and the onset of radiologically detectable hip osteoarthritis (OA) relate to one another in a group of former professional handball players.
- The article analyzes the correlations between hip ROM, osteoarthritis (OA), and pain, as well as the risk of OA in elite handball players over the long term.
- Twenty former professional handball players and thirty-nine healthy controls made up the study's sample size.
- The handball players' medial rotation and hip flexion are significantly decreased compared to the control values, while their abduction, extension, and lateral rotation were significantly increased.

2. Related works

Quickly picking and lifting heavy include carrying actions that cause a back muscle electrical stimulation signal to become considerably more active than it would in an upright, stationary position. Without the suitable handling techniques and tools, this raises the likelihood of back muscle damage. It creates a hip active actuator to aid human manual lifting to lessen overall risk of LBP while doing manual handling duties. To support human mobility, a power control technique is included to the control loop. The power output of the hip is represented by a power curve that mimics the human body's semi-squatting motion [13]. Numerous research works examined how well hip active exoskeletons work to minimize the incidence of lower back pain (LBP) when doing manual lifting duties. For example, the study [14] showed that when a hip exoskeleton was used to help with lifting duties, there was a considerable decrease in both muscular activation and compression pressures on the lumbar spine as compared to when lifting without support. A hip exoskeleton could assist in lowering the incidence of LBP as demonstrated by a study [15] that found using one reduced the activation of the lumbar muscles and the amount of metabolic energy used during frequent lifting activities. The findings showed that hip active exoskeletons are a helpful tool for enhancing manual lifting techniques and reducing the amount of stress placed on the lower back muscles. The impact of running tiredness on the lower limb symmetry, time, and stiffness in amateur runners was demonstrated by research [16]. The results provided early indications that exhaustion alters the symmetry of the lower limbs during running, which could have consequences for their comprehension of running-related injuries and efficiency. Based on the study of individual hip joint torque during gait and balance restoration, a unique computational stiffness model is developed. To create the necessary activity support torque profiles for dynamic walking and balancing aid, the simulated stiffness model is used. Based on the virtual stiffness model, the integrated active assist control architecture is then built. Walking experiments show how successfully the given control framework works [17].

It is common to see quadrupeds jumping. We watch the bobcat's jumping gait and break it down into its component parts to determine its joint motion law. A generic machine model of a quadruped robot is presented as a means to regulate the jumping gait of the CPG-based legged robot. Afterward, the actions theory of the joint drive curve and the concept of bionic implants re-couple the standard CPG control network [18]. In the present work, a fast adaptive neuro-fuzzy inference terminals controller with sliding mode for a hind limb musculoskeletal model is provided. This model consists of six muscles coupled to a planar model of a two-link rigid robotic manipulator. (FES). To solve the tracking problem, we use a decentralized fuzzy terminal sliding mode controller [19]. This controller is composed of several independent MIMO controllers, one for each component. The trajectory curves generated by computer programs depending on the combined GCDs fit the hip joint motion track, matching the expected forms of the exoskeleton. The EMG-driven speed control's human-machine inter-limb cooperation methods made it possible for the exoskeleton-treadmill system to automatically adjust its speed in accordance with the individual's intentions. The entire network may be utilized as a task- and goal-oriented training tool for patients with incomplete spinal cord hemisphere stroke who need gait restoration [20]. Theoretically, the Minimally Invasive Anterior Approach (MIAA) enables quick healing and reduces the need for retraining, although prior research has shown that changes to muscular and static balance may happen [21].

A typical goal of non-operative treatment for Femoroacetabular Impingement (FAI) condition is deep hip muscle restructuring. While it is believed that these muscles play a significant part in stabilizing the hip joint, it is not apparent if the hip disease affects how they function. This exploratory research looked at how people who suffered from FAI syndrome used their hip muscles throughout two pressing activities [22]. Hip dislocations are a frequent and clinically significant side effect of total hip replacement (THA). To avoid re-dislocations, hip-abduction braces are now utilized after surgical or non-surgical treatment of THA dislocations. Yet, there is an ongoing debate over the medical and biomechanics efficacy of such devices [23]. To investigate, with an emphasis on EMG and 3D motion kinematic data analysis, the lumbar-pelvic region's stability and muscular activation during core stabilization exercises. The purpose of the study was to determine how the pressure settings on the device affected hip mobility and muscular activation, as well as how these factors affected trunk and pelvic stability. The reformer is composed of a carriage that is held in check by springs and goes back and forth on rails [24]. Hip joint prosthesis serves to restore human hip joint function. With the most recent double hip joint prosthesis, the distinct component known as the outer liner acts as a shell for the liner element. There was never any research on the contact force produced on the most recent gait cycle model of a dual-mobility hip joint prosthesis. Ultrahigh molecular weight polyethylene was used to make the model.

3. Materials and method

Strict exclusion criteria and matching protocols were used to account for possible confounding factors introduced by choosing participants during consultations for severe polytraumatism. The inclusion criteria were established as comprehensive questionnaires that would be used for the participants to be subjected to trauma record analysis. This screening eliminated participants who had suffered previous multiple trauma or traumas involving their lower limbs, among others. Additionally, the different groups were pair wise matched to ensure similarity in sex, age, and the level of physical activity among the subjects in the handball playing and control groups. Performing the radiography evaluation of hip joints to obtain all details of prior medical conditions that can be causative factor of mid-study polytraumatism. In addition, the clearer the trails leading off the past history of low limb joint injuries between the groups generated using the questionnaires was made possible. By using these procedures, it was possible to confirm that the relationships that have been observed between hip range of motion, hip OA, and handball practice were actually caused by the factors of interest rather than trauma-related characteristics.

Table 1. Inclusion criteria for handball players.

	Handball players (*n* = 20)	**Controls (*n* = 39)**	***P* score***
Age (years) Range for Mean	44.9 (3.7) 37–53	42.5 (4.8) 33–52	0.06
Weight (kg)			
Mean (SD) Range	80.7 (12.2) 63–101	75.1 (15.0) 42–111	0.14
Height (cm)			
Mean (SD) Range	80.7 (12.2) 63–100	17.5 (8.3) 151–191	0.13
Training volume (hours/week)			
Mean (SD) Range	6 (1.3) 4–7	0.2 (1.1) 0–4	<0.0002
Index of body mass (kg/m^2)			
Average (SD) Range	24.1 (3.1) 21–33	24.9 (4.8) 16.33	0.18
Heavy worker% (No.)	18 (3)	51.2 (22)	
Lifetime instruction in handball (years) Range for Mean (SD)	25.7 14–41	0.4 (1.8) 0–11	<0.002

All male handball players between the ages of 37 and 54 who had previously competed at a competitive level for one of two teams were included in the experimental group. Everyone had a combined total of at least 15 years of experience playing handball and trained a maximum of four hours per week. At the time of the exam, each participant had a healthy level of physical activity and had not suffered any injuries. In the section on Orthopaedics, the test subjects and the normal controls were collected during patient consultations for serious poly traumatism. The age and body weight are such key contributors to the onset of osteoarthritis (OA), participants in the control group had their ages and weights matched. Both experimental and the control groups were barred from including male participants who had suffered hip joint injuries or abnormalities. Radiographic analysis and in-depth personal conversations gave details on these variables. The features of both categories are shown in **Table 1**. Before any testing started, all research subjects provided their full permission. The research was split into parts that gathered data on the risk factors that follow for hip OA: personal information including years and hours spent training for sports, lower limb discomfort or injury, medical histories of family members, and present joint issues in the lower limbs.

3.1. Hip radiography

Every individual received a radiographic evaluation of the hip. The posture of the joint, which is compatible with normal physiological or cycles of joint loading, was internally turned at an angle of 15–20 area enclosed among both the interior of the feet. The Duquesne fake profile was used to analyze radiographs taken while the patient was bearing weight in the coronal plane at a 1:1 scale to determine the anatomical hip values. The JSW and its position, in addition to osteophytes, osseous cysts, and subchondral sclerosis, were all identified using radiography. This measure reveals details about the tissue's condition, including its thickness and deformability under strain. When the hip joint is carrying weight during radiography, the femoral head is guaranteed to be pushing into the acetabulum, making JSW measures more accurate. Using a goniometer, for the hip, the passive ROM was measured symmetrically and measured in degrees. There were measurements for each joint action: hip abduction, adduction, medial and lateral rotation, and hip flexion. Until the activity was finished or the pain threshold was achieved, the joint motion was sustained.

Each variable's normality assumption and variance homogeneity were established, enabling parametric statistics. **Figures 2** and **3** depict the prevalence of radiographic osteoarthritis of the hip of men and women. The threshold for statistical significance was set at 0.05. The probability of hip OA was evaluated using the $x2$ test, and the subject features and passive ROM were assessed using the student's *t*-test. The Pearson correlation coefficient was used to illustrate the association between ROM and OA, pain, and JSW. The function and pain data were compared using the Mann-Whitney U test.

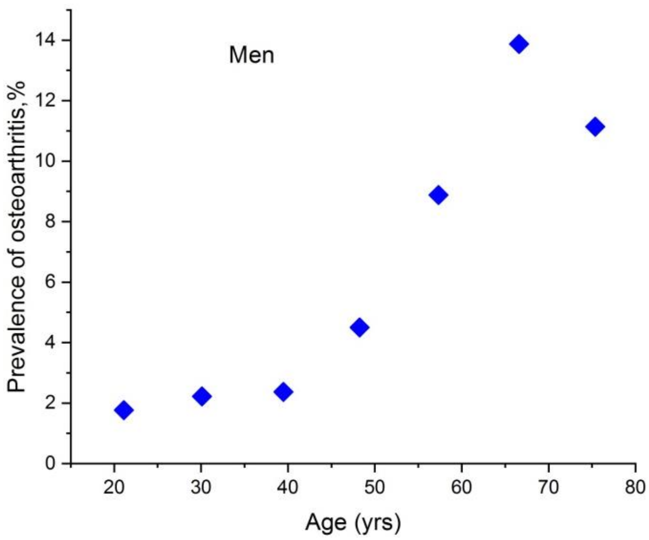

Figure 2. Prevalence of radiographic osteoarthritis of the hip of men.

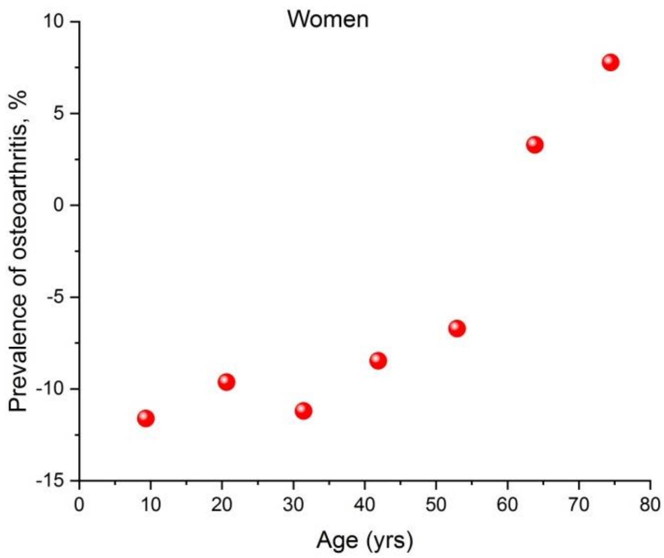

Figure 3. Prevalence of radiographic osteoarthritis of the hip of women.

The handball players said walking normally caused minimal difficulty; however, getting up from a sitting posture seemed to cause the greatest suffering. **Figure 4** denotes the diagram of osteoarthritis pathogenesis. Generally, the OA athletes reported minimal hip discomfort. The findings of this research suggest a link between competitive playing handball and growing hip OA. When factors including age, physical activity, load throughout a game, and BMI were considered, the findings suggested a link between frequent training and hip OA. The function and pain condition of the two groups is shown in **Table 2**. When the players having OA were compared to the controls having OA, there were no significant differences in their Lequesne ratings or WOMAC functional subscores.

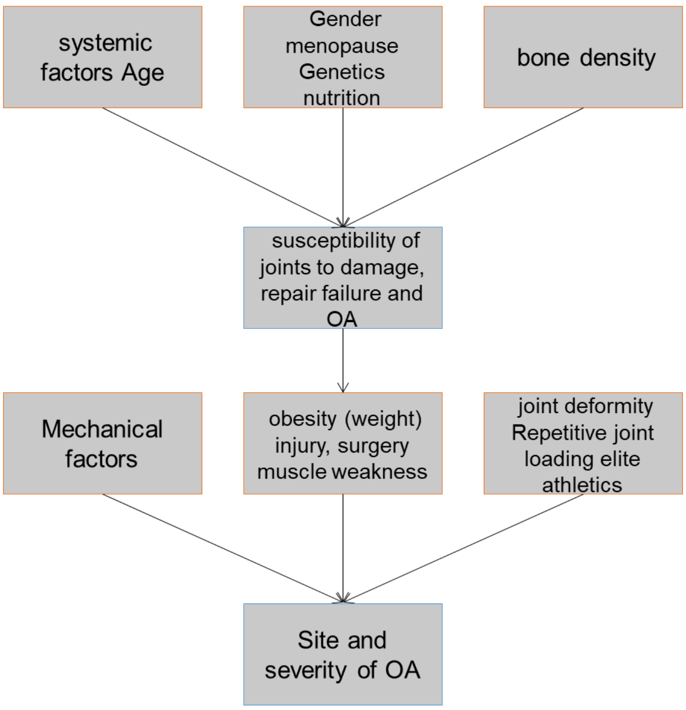

Figure 4. Diagram of osteoarthritis pathogenesis.

Table 2. Radiological range of motion in categorization

	Handball players (*n* = 21)		Controls (*n* = 39)		Total hips (*n* = 117)	
	Right hip	**Left hip**	**Right hip**	**Left hip**	**OA hips (*n* = 21)**	**Healthy hips (*n* = 97)**
Range (*) Mean (SD) Flexion	111 (8) 91–121	113 (12) 72–123	120 (7) 100–122	111 (14) 100–121	112 (14) 71–122	118 (9) 91–121
Abduction (°)						
Mean (SD) Range	41 (5) 31–51	38 (8) 20–51	25 (3) 20–33	27 (3) 20–33	27 (3) 20–33	33 (8) 20–51
Extension (*)						
Mean (SD) Range	12 (7) 4.42	12 (8) 4–45	3 (1) 0–4	5 (2) 0–4	11 (12) 0–41	6 (5) 0–41
Abduction (°)						
Mean (SD) Range	22 (9) 10–41	21 (12) 5–41	23 (3) 20–33	28 (3) 20–33	34(12) 22 –55	33 (8) 3–41
Medial rotation (*)						
Mean (SD) Range	15 (8) 4–32	15 (7) 0–21	20 (2) 11–14	22 (3) 10–21	15 (6) 0–31	22 (3) 10–33
Lateral rotation (*)						
Mean (SD) Range	29 (8) 11–52	28 (6) 110–42	22 (2) 10–23	24 (2) 20–33	24 (8) 14–4	24 (5) 11–51

3.2. Displacement subgroups

It is shown that the associated reconfiguration manifolds of displacement subgroups, which are specified holonomic joints as a group, are in fact linked. In this part, lie groups are provided. The required and sufficient conditions are stated in Proposition 2 for the exponential comparison of these maps' configuration manifolds to be surjective. Considering the displacement discovered subgroups, a new set of joint variables known as screw collective variables is offered. Physically speaking, these new joint parameters correspond to the initial classic connection velocities on the relevant relative arrangement manifold for a screw motion. Theorem 1 establishes a formal relationship among the traditional joint variables and the obtained screw variables.

Define the distribution $D_j = T_{r_i^j} R_{r_j^i(0)} \left(D_i^j\right) \subseteq TP_j$ for a joint holonomic. D_j is involutive, or its galaxy of parts is complete under the lie brackets of nonlinear functions on P_j, according to the concept of a joint holonomic. If D_j is left-invariant, then this bracket corresponds to the definition of a Lie bracket on Lie (P_j), i.e., $D_j(r_j) = T_{e_j} L_{r_j} \left(D_j(e_j)\right), \forall r_j \in p_j$. The integral manifold of D_j containing e_j is represented by $Q_j \subseteq P_j$. In particular, $T_{e_j} Q_j = D_j(e_j)$ comment thread of Lie because $D_j(e_j)$, an extended subdomain of Lie (P_j), under the Lie bracket of Lie is shuttered (P_j).

Proposition 1. *If D_j for a holonomic joint is left-invariant, then e_j, i.e., $Q_j \subseteq P_j$ is a particular k-dimensional interconnected Lie subset of P_j the with Lie algebra Lie $\left(Q_j\right) = D_j(e_j)$. Be aware that by left interpreting Lie $Q'_j \subseteq P_j$, and right assembling it with $r_i^j(0)$ a specific involutive distributed matching to the holonomic* *joint exists for every Lie subgroup Lie* $\left(Q'_j\right)$ *over* P_j.

Notice that by left translation Lie $\left(Q_j\right)$ over P_j and correctly composing it with r_i^j, one may get a specific involutive distribution that corresponds to a holonomic joint for each Lie subgroup $Q_j \subseteq P_j(0)$.

Definition 1. *When a holonomic joint's effective distribution* D_j *on* P_j *is left-invariant, displacement subgroup is used.*

Subgroups of the linked lie of SE (3), the usage of conjugate up to identify various displacement subgroup types based on Proposition 2 and the fact that $P_j \cong$ SE (3). This table shows that the six the prismatic, kinematic pairs of revolute, cylindrical, helical, planar, and spherical joints, and combinations of them, make up the lower displacement subgroups. Hence, the kinematic pairings in this combined classification in the lower relative configuration manifolds are categorized as SE subgroups. Other holonomic joint types, such as universal joints and higher kinematics pairs, exist but are not classified as displacement subgroups. Nonetheless, these joints' relative configuration manifolds are not SE subgroups. To create equations that characterize the relative configurations manifold of these joints, one has to multiply specific foundational components by exponentials in the tangential space of the compared configurations manifolds at the identity element.

Proposition 2. *With the exception of a helical joint at a three-of joint is joined with such a two different. Prismatic joint, in which case the helical joint axis goes. The group exponential map is parallel to the plane of the prismatic joint exp: Lie* $\left(Q_j\right) \rightarrow Q_j$ *is predominant form for all subcategories of displacement subgroups. In the article, this example is divided into two different joints.*

Definition 2. *Let* φ *be coordinates of a region on a map* e_i, *by proposition 2 every relative manifold configuration* Q_i^j *of A displacement subgroup may have vector parameters* $s \in R^k$, *referred to as screw joint parameters, so every* $r_i^j \in Q_i^j \subseteq P_i^j$ *can be expressed as*

$$r_i^j = \exp\left(T^j_i s\right) * r_i^j(0) = \exp\left(\left(Ad_{r_i^j(0)}\right)(d_{ei}l)(d_0\varphi)s\right) * r_i^j(0), \tag{1}$$

The connection between (s, s) and (q, q), the traditional common characteristics and their speed, may be summed by applying the following theorem for a relative movement r_i^j:[0, 1] $\rightarrow$ Q_i^j.

Theorem 1. *Have a look at a coordinate chart for a displacement subgroup* Q_i, $\varphi{:}\cup \subset R^k \rightarrow W$ *such that* $\varphi([0, \ldots, 0]) = e_i$, *and a relative motion* $r_i^j{:}[0,1] \rightarrow Q_i^j$ *in the neighborhood* $= L_{r_i^{j(0)}}(W) \subseteq Q_i^j of r_i^j(0)$ *.Then* $r_i^j(t) = \exp\left(T_{{}^j_i s}(t)\right) * r_i^j(0)$ *such that* $s(0) = 0$, *and*

$$\begin{gathered} q(s) = \varphi^{-1}\exp(d_0\varphi s) \\ \dot{q}(s, \dot{s}) = z(s)\dot{s} \coloneqq \left(d_{qs\varphi}\right)d_{ej}L_{\exp\left(d_{0\varphi s}\right)}\left(\int_0^1 \exp\left(-xad_{d0\varphi s}\right)\mathrm{d}x\right)d_0\varphi\dot{s} \end{gathered} \tag{2}$$

where $Lie(Q_j)ad_\eta{:}\, Lie(Q_j) \rightarrow (Q_j)$ is an endomorphism of $Lie(Q_j)$ such that $\forall\xi \in Lie(Q_j)ad\eta(\xi){:} = [\eta, \xi]$. The linear map $Z(s)$ is an isomorphism between $T_q\mathbb{R}^k$

and $T_q\mathbb{R}^k$ if, and only if $add_{0\varphi s}$ has no eigenvalue $\{2\pi iZ|i = -1\}$.

For the corresponding motion $r_i^j \subset W'$, let $r_i = L_{r_j^{i(0)}} * r_i^j \subset w$ be the associated curve on Q_i. This bend on Pi is $l * \varphi(q) = L_{r_j^{i(0)}} * \exp(T_i^j s) = K_{r_j^{i(0)}} \circ \exp(T_i^j s)$ according to Equation (1) and the compatibility of the using an exponential map the conjugation and inclusion maps of the Lie groups. $l * \varphi(q) = K_{r_j^{i(0)}} * K_{r_i^j} * l \circ \exp(d_0 \varphi s) = l * \exp(d_0 \varphi s)$. Therefore, Equation (2), according to the inclusion map l embeddings are diffeomorphisms, much like. Equation (2) is differentiated, providing information about the curve parameter

$$\dot{q} = \left(d_{\exp(d0\varphi s)}\varphi^{-1}\right)\left(d_{d_0\varphi s}\exp\right)d_0\varphi\dot{s} = \left(d_q\varphi\right)\left(d_{d_{0\varphi s}}\exp\right)d_{0\varphi}\dot{s}$$

It is possible to display the differential of the exponential map for a lie group G to be ξLie(G) is

$$d_\xi \exp = d_{eL_{exp\in}} \int_0^1 \exp(-xad_\in)\,\mathrm{d}x \tag{3}$$

Hence, the proof for Equation (3) is completed by replacing Equation (2).

$Z(s)$, which is the composition of numerous linear operators, is defined in Equation (2), and it is only invertible if and to the extent that every linear operator is invertible. It is sufficient to examine the circumstances in which $\Theta := \int_0^1 \exp\left(-xad_{d_{0\varphi s}}\right)\mathrm{d}x$ is invertible. Since left translating is universal. A coordinate chart that shows diffeomorphism. Consider the $\int_0^1 \exp(-xz)\,\mathrm{d}x$ solution $z \in \mathbb{C}$, which is identical to the whole infinite dimensional function $f(z) = \frac{1-\exp(-z)}{z}$ such that $f(0) = 1$. Hence, the eigenvalues of Θ equivalent to $\frac{1-\exp(-\lambda_i)}{\lambda_i}$ where λ_i's consist of the eigenvalues of $add_{0\varphi s}$. The endomorphism of the lie algebra Θ is only invertible if there are no eigenvalues equal to zero $\lambda_i \neq 2\pi i\mathbb{Z}$, where $i = \sqrt{-1}$.

Theorem 1's last section additionally provides a requirement for the dimensions of the coordinates chart picture linked to the screw joint parameterization. According to this restriction, the coordinates chart P_j elements corresponding to a 2-radian rotation of an axis in A_j on P_jSE (3). Furthermore, take notice that the summation term in Equation (3) corresponds generally to the incommutativity of Lie $\left(Q_j\right)$ with regard to the Lie bracket and is identical to the identical abelian lie groups on a map.

4. Results

In comparison to the experimental group, the control group had a more significant proportion of participants reporting hard work: only 20 percent (n = 4) a significant level of physical contact was reported by handball players. Demands, whereas 51.2% (n = 21) of the control individuals did so. OA in at least one hip joint was medically diagnosed in 60% of the former top handball players, compared to 13% (n = 5) inside the control group, indicating a significant prevalence of the condition. This variation was substantial. The findings for the two groups andradiological categorization are shown in **Table 3**. In the experimental class, the left hip's cartilage thickness was changed more than the right hip's. The walls of the acetabulum where the reduction in

JSW was most frequently observed were the anterolateral quadrant (n = 6), the front (n = 3), and the back (n = 2). In the anterior and posterior horns, as well as underneath the fovea, osteophytes were seen. **Figures 5** and **6** show the joint symptoms and radiographic features of osteoarthritis in men and women. **Table 4** shows the results of OA.

Table 3. Results of radiological categorization.

Stage	Kellgren and Lawrence's standards	Handball players	Controls
0	Doubtful osteophytes		
1	Absence of osteophytes		
2	JSW has a modest reduction in osteophytes	8	3
3	Small osteophytes, subchondral sclerosis, osseous cysts, or all three are possible	2	1
4	Osteophytes and a significant reduction in JSW	2	1

Table 4. Results of radiographic grade.

Radiographic grade	Prevalence of pain (%)
0 to 1	15
2	45
3 to 4	65

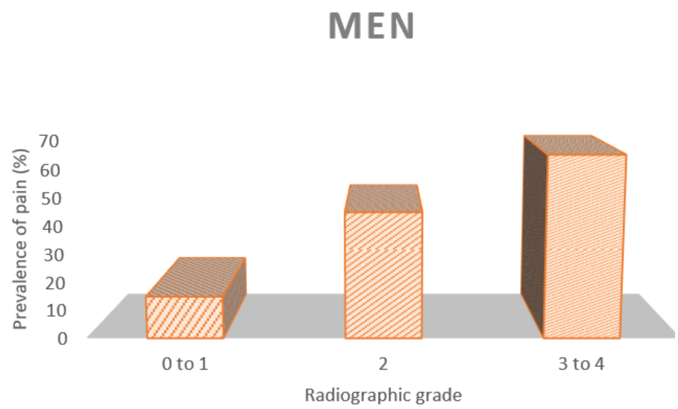

Figure 5. Men's joint symptoms and radiographic features of OA.

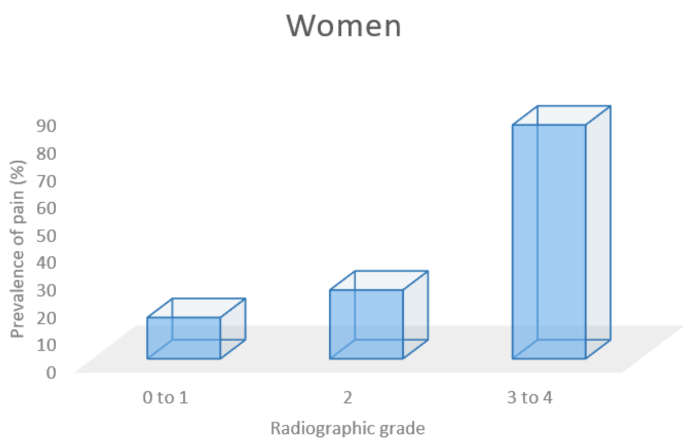

Figure 6. Women's joint symptoms and radiographic features of OA.

The specifications for the ROM of passive knee and hip are shown in **Table 2**. As compared to the ROM of the control group, hip flexion, and posterior rotation seemed considerably lower in the handball players. The handball players had more significant amounts of abduction, extension, and medial rotation. Adduction was affected because low hip flexion was also seen.

With OA, hip extension looked to be more significant. The degree of hip OA assessed, and the range of motion in the abduction and medial rotate on was shown to be negatively correlated. The negative relationship among hip OA intensity and ROM in abduction and internal rotation shows that as OA grows, individuals prefer to have less ROM in these motions. This finding emphasizes the effects of OA on joint motion, which can result in functional limits and low standards of life for affected persons. The operational and pain condition of the two groups is shown in **Table 5**. Compared to controls with OA, the athletes with OA had similar liquesce scores and WOMAC functional subscores.

Table 5. ADLs limitation of OA.

	Handball player		**Controls**	
	Healthy (*n* = 8)	**OA (*n* = 12)**	**Healthy (*n* = 8)**	**OA (*n* = 12)**
WOMAC functional subscale				
Median (quartile 1, 3)	0 (0, 0)	3 (2, 2)	0.4 (0, 1)	6 (5, 5)
Range	0–0	1–6	0–1	3–6
Pain subscale for WOMAC	0 (0, 0)	14 (0, 31)	0 (0, 0)	
Median (quartile 1, 3)	0–0	0–61	0–0	
Lequesne's median score (quartiles 1–3)	0 (0, 0)	2 (2, 3)	0 (0, 2)	5 (3, 8)
Range	0–0	1–8	0–1	2–11

Discussion

The findings showed that hip active exoskeletons are a beneficial tool for enhancing manual lifting techniques and reducing the amount of stress placed on the lower back muscles [15]. The findings showed that gait abnormalities persisted following THA by MIAA [21]. Additionally, the findings demonstrated that using an additional cushion may further restrict hip motion [23]. Furthermore, the findings demonstrated that individuals with FAI disease typically develop a defence mechanism when the hip falls into an impingement location and do not distinguish between descent and ascent when it comes to activating a variety of hip external rotator muscles [22].

In this study, compared to the control values, handball players' medial rotations and hip flexion were significantly reduced, but their abduction, extension, and lateral rotation were significantly increased. When playing handball, the OA participants in the control group experienced more hip joint pain during daily activities than the OA participants observed. Retired handball players seem to have a significantly higher risk of developing early hip OA than the general population. In contrast to other research results, these data demonstrate the variations in hip OA prevalence and range of motion across both control and experimental groups, offering understanding into the biomechanical difficulties unique to handball players.

5. Conclusion

Handball practice for an extended period of time appears to have a major impact on hip range of motion, which is related to the initial stages of hip OA. This extended calculation, which comes from differential geometry and Lie group theory, can be used to examine how forces and moments are distributed throughout handball players' several joints. Clinicians can detect possible locations of excessive stress on the hips by analyzing the interaction of these forces during handball-specific motions. This understanding can help build specific preventative measures or treatment strategies that reduce the chance of hip OA. Multi joints were categorized with this objective in mind, and the definition of a misplaced subset was expanded. The exponential map was developing for all but one kind of displaced subgroup, demonstrating that the comparison configurations manifold of such connections are now lie groups. The traditional joint parameters were formally linked to the screw mutual characteristics through the specification of the screw joint characteristics. The available data provides basis for integrating extra control measures into an integrated risk management schedule, such as creating preventative measures for potential young handball players. If young athletes changed their practice routine and used shoes with particular absorbent bottoms, they would have a greater probability of reducing the effects of the high mechanical stresses. Subjective self-report assessments may have difficulties in precisely estimating pain levels, and the measurement of pain during normal activities may not adequately reflect the intensity of discomfort experienced by individuals. Future advances may include wearable devices to monitor physiological reactions, combining objective data with self-reported metrics to provide a more thorough evaluation of pain throughout daily activities, improving accuracy and comprehension of difficulty levels.

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