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Physical activity patterns following major lower limb amputation

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ABSTRACT

Introduction and aim of study: Lower limb amputation is one of the most common acquired disabilities. The main aim of the study was to assess global trends regarding the procedure, investigate the current trends in post-amputation care, particularly in terms of returning to physical fitness, and identify potential fields of interest in order to improve the everyday life of people with lower limb amputation.

Materials and methods: The authors based this review paper on a widespread analysis of scientific articles published in Science Direct, PubMed, UpToDate, Cochrane, Springer, and Google Scholar, the 2021 Global Burden of Disease Study, and government platforms.

Results: The collected information emphasizes the existence of numerous barriers discouraging from participating in sports. The post-amputation care is crucial and requires a multidisciplinary team approach. Chronic pain restricts physical activity significantly. Different types of movement focused on specific muscle groups improve functionality.

Conclusions: Disability as a result of lower limb amputation is a significant social issue requiring more action to improve its visibility. New strategies ought to be implemented to educate people with disabilities on the importance of physical activity. The new technologies that are currently under investigation may bring some novelty to the topic in the future.

Keywords: Amputation, Artificial limbs, Rehabilitation, Para-Sports

BACKGROUND

Amputation has been defined by The International Paralympic Committee as the partial or total absence of bones and joints.[1] It is one of the most common disabilities that irreversibly affects a patient's life. Depending on the cause, amputations are divided into those induced by congenital defects, trauma and those secondary to comorbidities. In the young population, the most common cause of amputation was a traumatic mechanism, while in the elderly population, a vascular component is more prevalent.[2] The functional range of the limb may vary depending on which level was chosen as a final incision. The following modifications of the procedure have been described in the literature, categorized by the anatomical height of the cut: partial toe, toe disarticulation, partial foot resection, transmetatarsal, Lisfranc, Chopart, Syme, transtibial (long and short), through-knee disarticulation, transfemoral (long and short), hip disarticulation, hemipelvectomy, and hemicorporectomy.[3] This study is focused on major lower limb amputations and managing life and physical activity with a disability. Whether limb dysfunction is congenital, traumatic, or secondary to the underlying disease, it undoubtedly impedes performance in recreational physical activity. According to a study by Kars et al., practicing a sport before surgery significantly facilitates a return to physical activity.[4] Other sources pointed to older age, vascular comorbidity, and proximal amputation level as predictive indicators of physical inactivity after surgery. [5, 6]

REVIEW METHODS

The authors based this review paper on a widespread analysis of scientific articles published in Science Direct, PubMed, UpToDate, Cochrane, Springer, and Google Scholar. For amputation incidence and prevalence rates data from the Global Burden of Diseases 2021 database and government site System E-zdrowie have been collected. Paralympic media reports published

by The International Paralympic Committee have also provided information about participation rates in professional international events.

PREVALENCE AND INCIDENCE

According to the data collected by the Global Burden of Disease Study, the incidence rates of unilateral major amputations in the general population have been steadily increasing worldwide, reaching 11.12 per 100,000 population in 2021. [7] Over the years, European trends have appeared to have a declining tendency, though they still vary between countries.

The data published on the Polish government platform System E-zdrowie state that between 2019 and 2022, approximately 15,000 hospitalizations with an amputation procedure were reported in each of the following years. [8]

Underlying chronic diseases contribute significantly to the growing prevalence. Although the quality of care in developed countries is good, lower extremity amputations mainly occur as an outcome of wrong management in treating diabetic foot disease or peripheral arterial occlusive disease. [9] According to the Centers for Disease Control and Prevention, 80% of lower limb amputations are a result of complications from diabetes. The global prevalence rate of 244.21 per 100,000 population suggests the need for further investigation. [7]

The global incidence and prevalence rates in bilateral lower limbs amputation have been stable at 1.14 and 48.1 per 100,000 in year 2021, respectively. [7]

POST-SURGERY COMPLICATIONS

Amputation is a significant cause of long-term disability. It not only leaves a substantial mark on the body due to its mutilating nature but is also associated with stress, depression, and loss of interest in social life participation and physical activity, [10] which will be discussed in the latter part of the review.

The first wave of the surgery's outcome can lead to various complications, significantly impacting the patient's life. Surgical site infections are considered the most common among postoperative complications. [11] Wound dehiscence and stump infections are frequent, while their likelihood of occurring is higher in individuals with diabetes and those over 80 years old. [12] Surgical site infections (SSIs), as well as the formation of hematomas and seromas, heighten the risk of stump dehiscence and may necessitate revision of the surgery. This results in increased patient morbidity. [13] Deep vein thrombosis (DVT), characterized by the sudden formation of blood clots in deep veins, is one of the most severe complications following amputations. DVT can lead to pulmonary embolism, a possible cause of death. [14]

PAIN

Highly prevalent among amputees, regardless of the time since amputation, is chronic pain. We can distinguish phantom pain, residual limb pain, back pain, and nonamputated limb pain. [15] Phantom limb pain (PLP), described as pain that seems to come from the missing limb, can begin shortly after the amputation or may develop years later, though most amputees experience symptoms within the first year after the surgery, with a decline in prevalence over time. [16, 17] The research on 104 participants found that 48.1% of participants experienced residual limb pain, while 69.2% reported phantom limb pain. Residual limb pain was linked to limitations in activity. [18] Lower limb amputees experience lower back pain more frequently than the general population. The highest rates are among those with a sedentary lifestyle who don't engage in any sports, highlighting the need to educate this group on the benefits of physical activity. [19] Managing these chronic pain conditions is crucial due to the impact pain can have on both participation in physical activity and overall quality of life. [20]

REHABILITATION

Since the fundamental element of the surgery revolves around the loss of the limb and its consequences on gait, early intervention with core and hip strengthening exercises on both sides, focusing on maintaining pelvic stability during alternating leg movements, is essential. [16] The goal of rehabilitation following a lower limb amputation is to enhance physical, psychological, and social functioning. Rehabilitation typically emphasizes prosthetic training, which helps maintain or restore independence by improving mobility both at home and in the outside world. The recovery process also focuses on successfully reintegrating individuals into society. Establishing clear goals early in the rehabilitation process can boost motivation. [21] Even a brief yet intensive post-operative physical rehabilitation course has been shown to enhance both walking distance and walking speed. [22] Implementing a personalised plan for each amputee is advised. Research suggests a gradual and regular training approach to reduce the risk of re-injury to both the residual and contralateral limbs. [23] During rehabilitation, participants showed substantial progress in various areas, including reduced PLP symptoms, improved running gait, and enhanced mood function. [16] In terms of prosthesis usage, rehabilitation enhances hip muscle strength in the residual limb and improves grip within the prosthetic socket after transfemoral amputation, which even makes running possible. Since hip strength declines in those who do not participate in the training, regular strength training is recommended to maintain limb strength post-amputation. [24] Consistent treadmill use improves balance and walking skills, offering benefits in terms of energy costs and fatigue, even for those who are already well-functioning. [25] Despite global efforts to promote physical

activity and spread awareness, a study shows that most individuals with lower limb amputations (61%) did not engage in enough exercises to be considered „adequately active". Rehabilitation specialists can be instrumental in encouraging these persons to be more involved in physical activity. [26]

PROSTHESIS

For a person after amputation to uphold physical activity, a certain level of functional capacity is needed. A prosthesis is an artificial device designed to replace a missing body part and is utilized to restore or compensate for lost function. The prosthesis can help alleviate the difficulties faced by individuals with amputations by providing a functional limb that enables them to manage daily tasks. For some, a prosthesis symbolizes a return to independence and becomes an integral part of their identity, a concept known as prosthetic embodiment. [27] The selection of a prosthesis should be as personalized as the necessary training plan, taking into account the specific demands of the activity, the level of amputation, and the type of sport its user wishes to pursue. [28] A well-chosen prosthesis, combined with a properly relearned gait pattern, can allow locomotion with energy expense comparable to a healthy person's. A suitable prosthesis ensures that the challenges of having an artificial limb do not significantly hinder mobility or the ability to engage in professional activities. The assessment and design of the prosthesis should be adjusted to the individual's needs, the sport, the level of competition, and the environment. It's crucial to consider the person's goals, preferences, and the equipment cost. In some cases, a single prosthesis may be suitable for both daily activities and sports participation, while in other situations, various sports may require different prostheses. Using a prosthesis outside of its intended purpose can lead to injury or damage to the device. A prosthetist with expertise in this sports domain, dynamically sprouting with news and changes, is an essential part of the support team for both recreational users and professional para-athletes. [29] Some amputees find their prosthesis to be an impediment in activity or prefer not to use it, opting instead for wheelchair sports or other tasks where the prosthesis is unnecessary. While the prosthesis itself may not directly motivate sports participation, it can indirectly encourage athletes to maximize its use. [6] Given the example, running-specific prostheses (RSPs) have been shown to impact engagement in sports and physical activities positively– however, issues such as balance difficulties and discomfort from leg length discrepancies or poorly fitting sockets can reduce daily wear time. [30] Hence, factors such as the prostheses' weight and the strength of its elements are important considerations. [23] The design, fitting, and training associated with the prosthesis should aim to minimize limb strain.

[31] A properly adjusted prosthesis has also been found to alleviate lower back pain in individuals with LLA. [32] Whether the prosthesis will be used exclusively for sports or also for daily living activities- it will influence its design. A prosthesis intended for daily use may have more cosmetic considerations than one designed solely for sports. It is essential that the prosthesis is user-friendly and easy to adjust, especially with sports prostheses that may require modifications before and during activities. *[28]* The effective use of a prosthesis after LLA relies strongly on thorough collaboration between both physical and psychological therapy.

NEXT STEP TOWARDS ACTIVITY

The choice regarding the genre of activity is influenced by factors such as gender identity, the energy demands of the sport, and the impact on a prosthetic limb. [33, 34]

Common sports among amputees include walking, fishing, swimming, golf, cycling, and general fitness. [35] Some sports require adaptations to accommodate the needs of amputees, allowing them to participate in an altered form. [21] And so, LLA survivors often need prosthetic devices to engage in sports. A European study of seventy-eight amputees, with a 35% sports participation rate, found that 23% used a specialized prosthesis to facilitate their sporting activities. [36] Following a lower extremity amputation, high activity levels are attainable, even having in mind such intense sports like downhill skiing and mountain biking. However, over the long term, many prefer moderate activities such as swimming and cycling, with swimming being the most popular. [21] Stamina is another factor that should be taken into consideration. Exercise is more strenuous for amputees than for people without disabilities. Moreover, patients after the above-the-knee amputation appear to have increased metabolic demand compared to patients with preserved knee joints. [29, 37]

A way back on the sport, exercise and recreation route is a bumpy one – a complex process that requires collaboration from a versatile team, having the newly formed athlete at the center to ensure entertaining and safe time. [38]

ACTIVITY – THE IRREPLACEABLE DRUG

Regular engagement in physical activities is widely recognized as a key aspect of maintaining a wholesome and wellness-oriented living. [6] Sport and recreational activity involvement offer numerous psychological and physical benefits for amputees, which makes movement an essential component of optimal rehabilitation and community inclusion. [29] Individuals who take part in adapted sports report crucially higher quality of life (QoL) and life satisfaction rates in comparison to those physically impaired who do not engage in such activities. [39] Physical activity is beneficial for those facing physical or psychological challenges, or both, as emphasized by various international health organizations. [40] Participating in activities

positively impacts a handful of life aspects, including physical health, self-esteem, concentration, problem-solving abilities, and is related to stress reduction. [41] Persons after unilateral LLA can also benefit from adapted sports in a way that such activity improves bone health [42] *and reduces phantom pain. [6]* Research indicates that physical activity can enhance body perception, mood, and self-esteem while also providing a social environment that fosters potent interpersonal relations. [43] Consistent exercise after surery upgrades functioning – both physical [44] and psychosocial [45], thereby reducing some of the challenges associated with amputation. [35]

NEW SELF AT CENTRE – CRAFTING A FRESH PERSPECTIVE

Limb amputation is a disability that markedly affects both physical and psychosocial functioning in a negative way. [46] Amputees frequently describe the process of adjusting to life after surgery as a redefinition of self-image and own identity. [47] Research indicates that individuals engaging in sports tend to have a better perception of their bodies, with studies showing a strong link between regular exercise and improved body image. [48-50]

Sports involvement can boost self-esteem, quality of life, overall health, self-efficacy, feelings of empowerment, and motivation to sustain such a state. [51, 52] Studies have proven that physical activity is a rehabilitation form for those with body image issues (e.g. resulting from cancer), with participants reporting a renewed sense of body awareness and an ability to change their self-perception. The influence of regaining physical control during the process was emphasized. [53] As the perspective and approach are gradual, amputees appear to be more enterprising and vigorous in taking action, problem-solving and less likely to be disheartened by obstacles or setbacks. [6, 41] Given the example, participants in the National Veterans Wheelchair Games reported significant benefits from the activity, such as better knowledge of sports equipment (92%), improved sports skills (89%), enhanced mobility (84%), and broader embrace of their condition (84%). Most of the players felt that the games positively impacted their lives. [45]

WHERE IS A GROUP, THERE IS STRENGTH

Regular physical activity involvement offers benefits to both disabled and able-bodied individuals. [54] Active time spent with persons who share similar challenges enhances confidence in one's own physical ability, as those of other players. [53] The social environment plays a major role in motivating to engage in physical activity. Since community interactions often decline after an amputation, sports can serve as a valuable way for people with LLA to connect with others, whether they have a comparable disability or not, fostering a sense of belonging. Sport engagement allows to release daily tension and be more at ease with

difficult emotions. The competitive aspect of sport, valued by all athletes, that can be directed either toward others or oneself, provides a way to demonstrate and cherish capability, define one's own limitations and strive to exceed them. [6]

PROFESSIONAL SPORT AND INCLUSION

The role of sports for individuals with disabilities has evolved from recreational activity to high-performance pursuit, as seen in events like the Paralympic Games. [55] Sports participation among people with disabilities saw remarkable growth in the second half of the 20th century. In 1948, the first Stoke Mandeville Games, a competition for wheelchair athletes, featured 16 competitors, *and in 1976 ambulatory athletes were also included. [56]* From 400 athletes from 23 countries in the 1960 Rome Summer Paralympics to over 4,200 persons from 148 countries in the 2008 Beijing Summer Paralympics. [57] In 2024, the Paralympic Games host 4,400 athletes from around the world, who will compete in in 23 disciplines. [58, 59] The Paralympic Games have become one of the leading multisports events globally, giving way only to the Olympics. It mirrors the overall rise in sports participation among individuals with physical disabilities. That way, sport – viewed as entertaining, popular, and pleasant activity – promotes health, fosters a sense of achievement, enhances self-confidence and positively influences the process of post-surgery body perception. [60]

However, athletes who intend to pursue a professional career in sports still face similar problems with the accessibility of the equipment. Better funding and, as a result, greater availability of high-quality assistive products and adapted sports infrastructure in highly developed countries result in a widening disparity between high and low-income countries. [61] So far, the gender gap between the number of men and women professionals in para-sports has been quite clearly noticeable. More recently, there have been efforts to raise public awareness and improve gender equity in sports- it has been announced that for the 2024 Paralympics, at least 1859 slots have been provided for female athletes, which is about 42% of the total number of paraathletes. The International Paralympic Committee is determined to improve female participation in the following years. [62, 63]

VIRTUAL PARTICIPATION IN SPORT – LIGHTS AND SHADOWS

Sports participation for people with disabilities has been recognized as a key factor in developing self-confidence and a sense of autonomy, as well as in promoting social inclusion and body awareness. [64] Although participating in high-profile events like the Paralympics might play an inspiring role and goal-setter for some, reaching the daily amount of physical activity that supports health should be a priority for all. The actual rate of sports participation among lower limb amputees is significantly lower than previously estimated. Despite well-

known physical and psychological benefits for well-being sprouting from exercising and all potential advantages for individuals with LLA, physical inactivity is more common. [6, 39] Factors like the age at the time of amputation and the number of prosthesis sockets used so far had no impact, although the advancing age of amputees did have a negative effect. [21] Also, sports participation was found to be negatively influenced by aspects including amputation due to vascular causes, a higher level of amputation, and a lack of prior involvement in sports. [35] A reduced physical activity rate was observed among unemployed persons and those living with others. [26] Engaging in high-intensity physical activity can be particularly challenging for individuals with LLA due to residual stump issues (pain, ulcers, and other skin-related problems)[65, 66], limitations of prosthetics, reduced fitness, maintaining balance difficulties, lack of confidence, increased energy requirements, low motivation, or concomitant diseases. [26] Athletes with amputations show different patterns of spine injuries depending on the location of their limb loss – in case of lower limb deficiencies, they tend to sustain more injuries affecting the lumbar spine. [29] They also experience the escalation of muscle pain, which could be attributed to the additional strain placed on the remaining parts of muscle compensation for the lost ones. [35] The remaining limbs, due to their compensational function, are at risk of developing overuse injuries – Achilles tendonitis, plantar fasciitis, and stress fractures. Also, excessive crutches usage leaves a significant impact on the upper extremities. [29] For many LLA survivors, the reason behind decreasing sports participation lies behind a prosthetic barrier relating to poor fit and the high cost of specialized equipment. [35] The feeling of inadequacy and shame, condescending stares in social settings along with a lack of someone to take part in sports with are also a concern that leads to distress for individuals with LLA. Meanwhile, technical and psychological challenges were most frequently cited as encountered barriers, overcoming trivialization coming from other people and self-perceived lack of suitability for sports proved to be even more difficult. [6]

ACTUAL PREFERENCES

Both quality and quantity of sport are weakened due to the amputation.

A study conducted by Nissen et al. highlighted that following a LLA recreational activity was among the most significantly affected areas of life. [67] The strenuous need for constant adjustment leisure activities, either by reducing their frequency or by substituting them with different ones, was also underlined. [68] However, individuals with lower limb loss could and should be a part of the sports community and are encouraged to do so. [23] The odds of participation in any physical activity after an amputation are greater for those who were active

prior to the surgery. [4] Despite this, new standards rarely mirror those before the amputation. Reality does not match expectations, more obstacles than advantages arise, and the will to adopt and maintain motivation is laborious. [69] Those who do come back to leisure or sports activities often choose less demanding options, such as swimming and fishing, where prostheses may not be a necessity. [70] Some people have reported returning to being a soccer player after amputation, but no longer at the competitive level they once enjoyed. [21] Additionally, certain ones – golfing, skiing, jogging, dancing, bowling – were described as challenging after amputation. [68] With time passing by, there seems to be a decline in active sports involvement. [21] A decrease in participation was observed across all categories of leisure activities in comparison to pre-amputation levels, particularly in areas such as crafts and outdoor activities. [71] Domestic and more passive ones like watching television and listening to the radio are most commonly reported forms of physical activity. [26]

A FIELD TO ACT

Losing a limb, whether partially or entirely, should no longer be an obstacle and exclude amputees from the world of sports. Engaging in physical activity is crucial for health, fitness, and reentry into society. Specialists in many fields have a significant role in assisting, guiding, and supporting people after LLA in overcoming encountered barriers on the way to reintegration with sport – encouraging participation and preventing dropouts with an alert and patient approach and a thoughtful eye. While major sports events covered by media can serve as an inspiration, raise morale, and build up motivation, it is a simple leisure-related activity through which clinicians can promote and increase a healthy lifestyle. [26] Attentive surveillance over capacity, continuation, and type of training, as well as body measurements, can lead to injury prevention. [29] Commonly cited obstacles include insufficient facilities, transport difficulties, not being treated as an equal, health issues, low motivation, or a sense of alienation- these are barriers that leave space for change and are an invitation to act so that amputees can perceive their body as complete, fit and potent to push beyond its limits. [6]

DIP INTO THE FUTURE

Limb allotransplantation is a constantly developing field with incredible potential to improve patient's quality of life as an alternative to prostheses. Operative techniques for upper limb and facial transplantation have been better described in the literature, while only five cases of lower limb procedures have been reported to this date. [72] Three of them failed due to complications. The most recent transplantation took place in 2017 – the assessment in a follow-up showed regained joint movement, deficits in sensory and motor innervation, and developed lymphedema.[73] Other disadvantages of such an option are the need for immunosuppressive

treatment to prevent limb rejection and the long recovery and rehabilitation time needed to improve limb function. [72] On the other hand, in a survey conducted by Carty et al., participants with disabilities were enthusiastic about the idea of allotransplantation – of the 770 people, as many as 43% would like to undergo evaluation, leading to lower limb transplantation. For them, the knee or ankle joint recovery was the most important criterion for determining transplant success.[74]

Another type of intervention is autologous fat grafting. The main objective of this low-invasive procedure is atrophic scar tissue regeneration and improving stump adaptation to the prosthesis. Unfortunately, the effect is not permanent – the majority of the graft was resorbed 6 months post-intervention. [75]

CONCLUSIONS

Disability as a result of lower limb amputation is a common condition affecting life in a variety of ways. It is a significant social issue requiring more action to improve its visibility. The collected information emphasises the existence of numerous barriers discouraging from participating in sports. The post-amputation care is crucial and requires a multidisciplinary team approach. New strategies ought to be implemented to educate people with disabilities on the importance of physical activity. The change should be focused not only on the technical aspects, like prostheses and rehabilitation but also on creating safe spaces for restoring self-confidence and changing the perception of body image individually and in groups.

The new technologies that are currently under investigation may bring some novelty to the topic and further facilitate scientific progress.

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