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Assistance to a Patient during Sit-to-Stand Motion using a Walker: A Literature Review

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Abstract - This paper analyses the different aspects related to the four-legged walker frames that help a patient recover from their ailments affecting their legs, waist and back. Various configurations, materials, structural and mechanisms were studied for reducing the risks of fall, imbalance and injury to the user.

Key Words: Walkers, four-legged, sitting-to-standing, standing-to-sitting, hips, literature review.

1. INTRODUCTION

It is a universally known fact, with advancing age, come numerous ailments. These ailments can come in the form of skeleton-muscular weakening, inherited diseases or injuries due to certain accidents. One of the most common problems faced by many patients and aged individuals, is that of lower back pain. Individuals try to ease this pain by the aid of a *walker* or a *walker frame*, with at least 4 legs. The walker frame transfers a portion of the user's net weight onto his/her arms and shoulders. Thus, his/her legs and in turn, the back and hip muscles are subjected to a reduced amount of load, reducing a significant amount of back and hip pain. However, what most of the walkers provide are relief during *standing* or *walking* states of the user's body. The user still has to perform the back and hip muscle-intensive actions of *sit-to-stand* and *stand-to-sit* movements. This problem is tackled by incorporating a mechanism attached or separate to the walker which helps the user to perform the sitting and standing motions more easily. Research is being actively carried out to develop such a kind of walker. Some of these researches have been studied here closely.

The purpose of this study is to review the published literature related to the techniques and designs developed for the purpose of aiding a user during sit-to-stand and stand-to-sit motions.

2. METHODOLOGY OF RESEARCH

The literature for this review was collected from Science Direct and Google Scholar. Numerous research papers concerning the subject of sit-to-stand aids and walker frames were studied to determine which ones were eligible for this particular study. Six papers were finally selected to be reviewed. These papers approached the subjects of walker usage, design and sit-to-stand and stand-to-sit motion aid differently. These six papers were then studied and systematically reviewed by us.

3. MATERIALS

In the paper by D. Poovathumkal, et al, four different configurations of a four-legged walker frame are explained, along with their material of construction. Here, they state that aluminium is the most preferred material to support the weight of the user and reduce the walker frame's overall weight as well. They justify the widespread usage with the relative ease with which light aluminium is obtained from bauxite as well as the favourable physical properties exhibited by the same. However, usage of other materials like mild steel for structural uses (AISI grades 1005 to 1025) and cast iron, whose properties are close to that of aluminium are not discussed. Yu-Yang Lin, et al stated the use of stainless steel as the material of choice to construct their three designs.

The remaining papers (Jean-Pierre Merlet, Stephane Lopes et al, and P. Médéric et al) have not delved into considering their material of choice for their respective walker designs. This leaves the question regarding the material constants to be assumed during relevant calculations.

4. MECHANISMS

P. Médéric, et al use a simple kinematic system that uses linear actuators to help support and balance the user as he/she

sits down or stands up. This system has two degrees of freedom which are achieved using two separate joints. One allowing the centre of mass on the user to be easily lowered by increasing the distance between the wheels for a wider base and the other lowering and raising the handle bars the user holds.

J-P Merlet makes the use of a robotic ANG (Assisted Navigation Guide). It uses force sensors/transducers to detect a fall and a computer controlled bi-stable electromagnetic system to act as a clutch that holds and releases the walker wheels as it moves, based on an Oldham coupling. However the ANG simply aids the user while walking by helping they distribute their weight and balancing their movements and the hip and lower back muscles are largely not taken into consideration. The author also mentions the possibilities of the user receiving ambiguous or erroneous signals through the sensors occasionally.

Lopes, et al propose two self-locking mechanisms for walker frames in their paper. Both approaches use a single mechanical system for halting the frame during walking. The first approach uses more both gears and a spring while the second approach uses a relatively simpler and more efficient system consisting simply of a single spring. Both the systems are based on the same principle; whenever the user wishes to apply the brake, he/she presses down the hand bars against the spring force, making the slotted front legs press down on the ground. However, great scope of improvement in the braking system has been noted. The sitting-to-standing and vice versa processes are not discussed.

Yu-Yang Lin, et al put forth three unique structural modifications to support the user while performing the sitting-to-standing and standing-to-sitting processes. The authors propose three configurations, namely B, M and I types which balance out the shifting forces exerted by the user and prevents slippage. Out of the three, B-type of walker was most preferred by the testing individuals and 10% faster motion was observed while using type B.

D. Poovathumkal et al have discussed the materials and basic designs of four legged walkers in their review. Four types of walker design: Standard, Rollite, Rolling and Walkite Walkers are discussed in brief and the materials of construction are enlisted. Fundamental advantages of the individual walkers are mentioned as well.

Geoff Fernie et al, have provided a detailed mathematical study to design a better walker-frame. They propose that the frame be designed in such a fashion as to bring the user's centre of mass as close as possible to the wheels (with brakes provided preferably) at the base, so as to minimize the chance of the walker tipping backwards and causing injury to the user. The proposed mechanism, similar to the one put forth by P. Médéric, et al to dip and rise as per the user's requirements and increases and reduces the wheel base simultaneously. To provide greater stability while walking, additional removable weights are provided to be attached to the frame. Detachable weights make the packing and unpacking of the walker from storage easier while also allowing the user to maintain balance while moving.

5. RESULT

Through various approaches, novel designs for walker-frames for patients and other users have been made by the various authors. Poovathumkal, et al through their review have found that the most widely used and favourable materials for industrial purposes and also make good raw material for the walker construction. Both are fairly corrosion resistant and light in weight. J-P Merlet's design based on ANG system has provided the same motion range to the user as other mechanically assisted systems with much lower energy requirement as well as weight. The solar panel provided with the system also improves this range by a considerable amount. The model however, is to be calibrated for an elderly user and can also be used to calibrate the 3D kinematic model of any human being. Yu-Yang Lin, et al found out that the proposed B-type design have been reported to be better than conventional N-walkers, with 54.6% of the test subjects reporting greater satisfaction. It is noted however, that weakness in the upper extremities of the user may pose a problem. The design for the walker by P. Médéric, et al can exert a considerable actuator force to aid the patient while sitting and standing up so as to balance their shifting weight and torques generated. The prototype also aims at helping the patients overcome their post-fall syndrome (physiological or psychological impact of experiencing a fall) and induce confidence.

Results of the research conducted by Lopes, et al has drawn the result that even though the proposed self-locking designs reduced the overall effort required by the test subjects, measured in terms of Physiological Cost Index, the users expressed insecurity regarding the braking systems. The second approach was deemed more insecure than conventionally available ones. Fernie et al have concluded from their mathematical analysis, that for an ideal walker, high coefficient of friction and low centre of gravity should be used as much as possible. The second configuration proposed by them is the most ideal one for the purpose of sitting-to-standing motions and the third configuration is the most comfortable for normal usage. However, due to limited knowledge of dynamic behaviour, only theoretical values and designs could be derived by the authors. Also, the system's behaviour in case of uneven weight distribution and non-smooth terrain has been ignored.

6. DISCUSSION

Six papers were studied for this review paper, and the clearly evident flaws in them were pointed out. The common flaw observed in these papers was that the hip and back muscle groups were largely ignored by the authors. The ability of the user to use these contraptions whilst being in a state of muscle weakness (in the extremities) was not discussed. Material properties were not taken into consideration at all in most of the papers. Lack of ergonomic considerations to make the mechanisms more user-friendly was also seen. The change in quality of life of the users is also a topic left unexplored.

3. CONCLUSIONS

There are various approaches and techniques being developed to make the usage of four-legged walker frames easier and beneficial for people recovering from ailments. Most of the studies focus on making the walking motion easier for the users, but ignore the sit-to-stand and stand-to-sit motions required by the users to use these walkers. This poses the problem, as ignoring this region can lead to severe repercussions in the future. It is also important to note that the precise knowledge of the raw materials required for constructing the walker frames is necessary to not only draw accurate design specifications as well as the estimated budget of the project. This factor has also been vaguely addressed in the reviewed papers.

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