A modified axillary crutch for lower limb amputees

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Abstract
Objectives: The standard axillary crutch is known to cause general discomfort to the user and crutch palsy. Aim of this pilot study is to compare a modified axillary crutch with the standard aluminum crutch. The following modifications were made in the new design (patent – LK/P/15/866).

1. A single pole design
2. Improved axillary and back support
3. Shock absorbing mechanism
4. Adjustable hand grip

Methods: Twenty normal subjects were used initially to ensure the safety and 20 amputees were later assessed. Both groups were studied before and after walking a distance of 50 meters using the standard and the modified crutch. Each subject was assessed three times on each crutch and the mean values were taken. The energy expenditure index (EEI) was calculated for each subject.

The stability and comfort were assessed using a pre tested, close ended, self-administered questionnaire.

Results: Twenty normal subjects {median age 23years (22-25); M: F 7:3)}, showed a significant reduction of heart rate (standard v modified, 11: 5, p=0.00) and EEI (standard v modified, 5.84: 2.39, p=0.00). Mean increase in velocity (standard v modified, 2.17:2.11, p= 0.58) was not significantly high.

Twenty amputees {median age 63 years (35-90); M: F 5:1; AK: BK; 6:14; median duration of crutch use 6 months} showed a significant reduction of heart rate (standard v modified, 20: 14, p=0.00) and EEI (standard v modified, 10.59: 6.89, p=0.01), and an increase in velocity (standard v modified, 1.94: 2.11, p=0.00).

Stability of the modified crutch was reported to be equivalent to the standard crutch by the majority in both groups {healthy volunteers; 14(70%), amputees; 13(65%)}. Comfort was considered to be better in the modified crutch by the majority {healthy volunteers; 15(75%), amputees; 12(60%)}.

Conclusions: The modification reduces energy consumption during locomotion, provides more comfort with an equal level of stability compared to the standard.

Introduction
Crutches have not changed significantly during their 5,000 years of use (1). There are many reasons - physiological and psychological - why it is good to stand and walk rather than sit and have wheeled mobility (2-4). Crutches improve the quality of life of lower limb amputees.

Traditional crutch designs are known to cause discomfort and complications such as crutch palsy due to the implied stress on the axilla (brachial plexus). Furthermore the user has to spend a considerable amount of extra energy for locomotion when compared to a normal individual.

The purpose of this study was to test energy efficiency and the level of comfort provided by a modified axillary crutch compared with the standard aluminum crutch.

Modifications made (patent – LK/P/15/866).

1. Improved axillary support with back support

   The axillary pad was ergonomically designed to fit the axillary curvature and increase the area of weight distribution. The extension of the axillary pad postero- superiorly supports the back and maintains better stability while walking and in the stationary position.

2. Adjustable hand grip

   This allows the user to adjust and maintain a better posture with reduced stress on palm. This also contributes to better weight distribution of the crutch.

3. Single pole design

   Reduces the overall weight of the crutch and gives better stability.

4. Shock absorbing mechanism

   Absorbs the collision shock of the crutch footpad with ground hence reduces the stress on the axilla as well as on the arm on locomotion.

Methodology

Twenty normal subjects and 20 amputees were assessed before and after using the standard and modified crutch. The normal subjects were assessed initially to ascertain the safety of the new device to be used on amputees.

The two most common methods to quantify energy expenditure during ambulation are the rate of oxygen uptake and heart rate (11, 12). Oxygen uptake is generally considered to be the most accurate measure; however, it requires subjects to wear a face mask that channels all the transpired gases to the appropriate instrumentation, which is usually mounted on a trolley that must follow the subject.

Heart rate is also used as a measure of energy expenditure (5-7). Most investigators have used maximum heart rate for this purpose. However, this does not take into account that different subjects may have different resting heart rates nor the effect of different velocities of walking on energy expenditure.

The measure of energy expenditure that was used for this study is the energy expenditure index (EEI), which is calculated as follows.

$$EEI = \frac{HR_{walk} - HR_{rest}}{V_{avg}}$$

Where :

EEI = energy expenditure index (beats/min)
HR_{walk} = walking heart rate (beats/min)
HR_{rest} = resting heart rate (beats/min)
V_{avg} = average velocity (m/min)

EEI has been shown to correlate well with oxygen uptake for sub-maximal levels of cardiovascular activity (8,9).

Heart rate was measured clinically and recorded for 30 seconds, after subjects had walked a distance of 50 meters on the standard crutch. Subjects rested ten minutes or more after each test, until their resting heart rates came down to the initial values; at which time the resting heart rate was recorded and the individual was allowed to walk on the modified crutch.

Students t – test was used to compare mean EEI values between the two designs10. The SPSS software was used to maintain the database and for analysis.

The stability and comfort were assessed subjectively using a pre tested, close ended, self administered questionnaire.

Results

Twenty normal subjects {median age 23years (22-25); Male: Female ratio - 7:3)}, showed a significant drop in; increase in heart rate (standard v modified, 11: 5, p=0.00) and EEI (standard v modified, 5.84: 2.39, p=0.00, figure 01). Mean increase in velocity (standard v modified, 2.17:2.11, p= 0.58) was not significantly high (Figure 1).

Twenty amputees {median age 63 years (35-90); M: F 5:1; AK: BK; 6:14; median duration of crutch use 6 months} showed a significant drop in; increase in heart rate (standard v modified, 20: 14, p=0.00) and EEI (standard v modified, 10.59: 6.89, p=0.01, figure 02), and an increase in velocity (standard v modified, 1.94: 2.11, p=0.00), as depicted in Figure 2.

Figure 1: Comparison of EEI of healthy volunteers

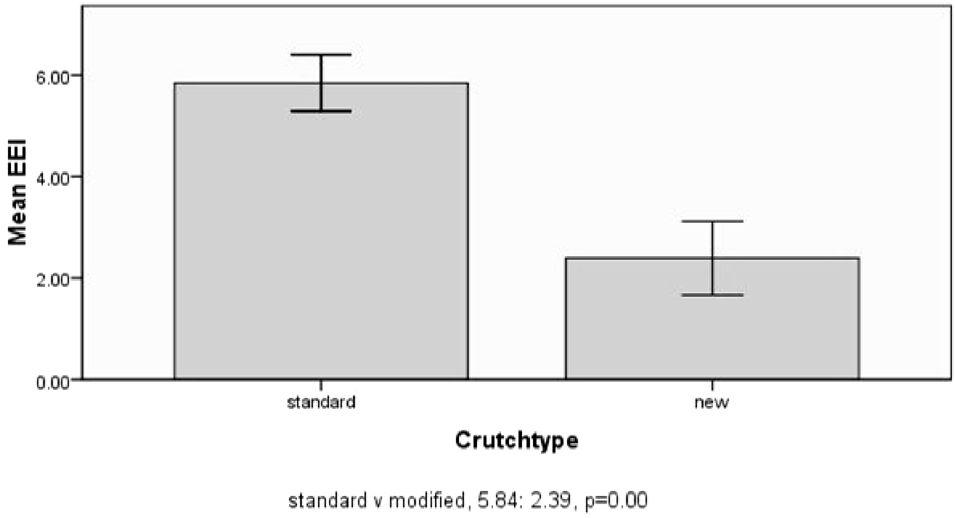
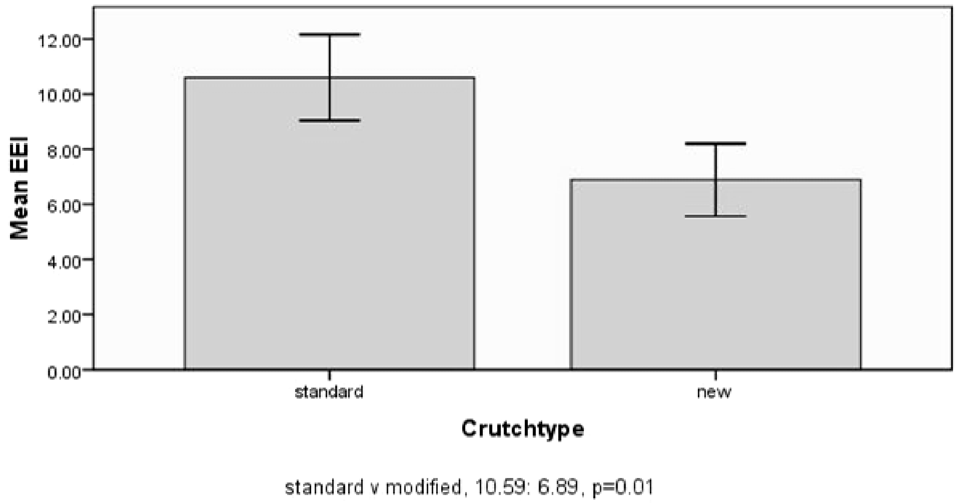


Figure 2: Comparison of EEI of amputees



Stability of the modified crutch was reported to be equivalent to the standard crutch by the majority in both groups {healthy volunteers; 14(70%), amputees; 13(65%)}. The comfort was considered to be better in the modified crutch by the majority {healthy volunteers; 15(75%), amputees; 12(60%), (Table 1, Figure 3)}.

Table 1: Subjective comparison of stability and control of the new crutch

	Stability			**comfort**		
	better	***same***	***worse***	***better***	***same***	***worse***
Control group	5	14	1	15	5	0
Amputees	7	13	0	12	8	0

Figure 3: Stability of the new design in comparison to the standard crutch

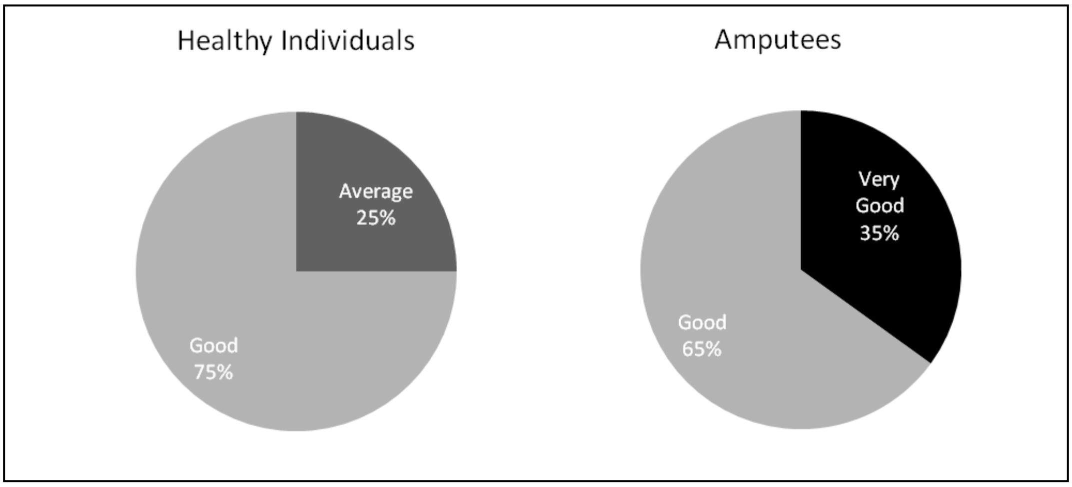
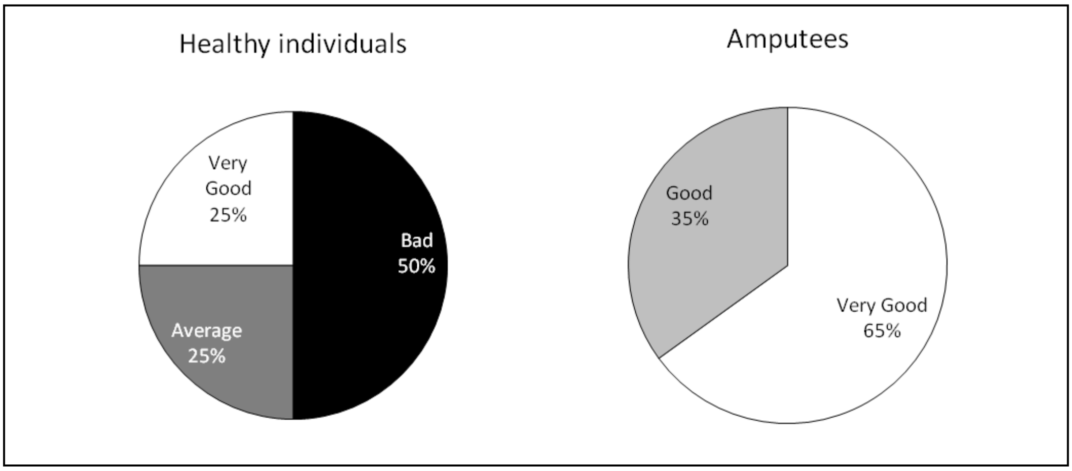


Figure 4: Comfort provided by the new design in comparison to the standard crutch



Discussion and Conclusion

Healthy volunteers were tested initially to ascertain the safety and stability of the new design. These were second year medical students who had no experience in crutch usage.

Recruiting amputees with >6 months of experience with crutches was difficult and time consuming as we have excluded all those with co – morbidities (diabetes, hypertension, ischaemic heart disease, bronchial asthma and with recorded visual abnormalities).

The walking velocity observed with modified crutch was similar to the standard crutch. Considering the fact that the amputees were trained and familiar with the standard crutch, the values observed with the modifications are expected to increase with long term usage. This needs to be addressed in a more detailed study in future.

The modification reduces energy consumption during locomotion; since the increase in walking velocity was not significantly different from the standard crutch, the reason points towards the reduction in heart rate indicating reduced muscular activity in comparison.

A few disadvantages identified with the new design was,

1. Prone to easy wear and tear as it was made from over the counter fitting and nuts and bolts, which were not purpose-built.

2. The shock absorber was added as a concept and alongside the provided comfort it increased the weight of the crutch.

3. Single pole design was achieved by using two different metals (iron and aluminum tubes), hence increasing the chances of rusting and wear and tear.

The new design provides more comfort with an equal level of stability compared to the standard aluminum crutch. We recommend further large-scale research to compare and contrast the new design with the existing axillary crutch designs. Furthermore we plan to continue improving the new cutch design to overcome the identified disadvantages.

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