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Physiological response to the ambulatory performance of hand-rim and arm-crank propulsion systems

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Abstract—Two types of propulsion systems—the hand rim (HR) and the arm crank (AC)—are commonly used in wheelchair ambulation. The purpose of this study was to investigate the physiological response of the two propulsion systems under actual locomotive condition by the actual users. The energetics of locomotion manual wheelchair (HR propulsion) and arm-propelled three-wheeled chairs (AC-propelled) at their free chosen speed (FCS) were studied and compared. Thirty-four male subjects with dysfunctioning lower limbs; 17 manual wheelchair users and 17 arm-propelled three-wheeled chairs regular users volunteered to participate in the study. Speed ($m.min^{-1}$), oxygen uptake ($l.min^{-1}$) and heart rate ($b.min^{-1}$) were monitored during steady-state ambulation at FCS for 5 min. Oxygen consumption (VO_2, $ml.kg^{-1}min^{-1}$), oxygen cost (VO_2, $ml.kg^{-1}m^{-1}$), net locomotive energy cost (kcal $kg^{-1}km^{-1}$) and physiological cost index ($b.m^{-1}$) were derived. The FCS of the AC propelled device is remarkably higher than the HR system, and the magnitude of the physiological variables of the AC propulsion system was significantly lower ($p<0.001$) in relation to the HR propulsion system, as revealed from the results of *t* test for two sample means at a significance level $p=0.001$. It can be inferred from the result that the AC propulsion system could be used for long distance rides with a higher speed required for outdoor ambulation and that the HR propulsion system is suitable only for indoor use, because of its excellent maneuverability where short-duration low-velocity ambulation is required.

Key words: *ambulation, arm-cranking, arm-propelled three-wheeled chair, energy metabolism, oxygen consumption, wheelchair.*

INTRODUCTION

The complexity and wide variation of mobility needs of persons with musculoskeletal disorders of the lower limbs necessitate the use of different wheelchair propulsion mechanisms. The propulsion mechanism should present an acceptable appearance, be reliable, and maximize the user's efficiency, independence, safety, and comfort. Two types of propulsion systems are very commonly used in India—the hand-rim propulsion system and the arm-crank propulsion system. The arm-propelled three-wheeled chair (APTWC) (1,2) or hand-propelled tricycle is frequently used for outdoor ambulation, which is based on arm-crank propulsion, as the standard hand-rim-propelled manual wheelchair (MWC) does not provide optimal efficiency in the situations where sustained locomotion is required at a higher speed. Most of the APTWC users in India are

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self-employed and use the APTWC as a permanent device of transportation and means of commuting to their occupational activities. A review of pertinent literature of ergometric studies suggests that from a physiological point of view, the arm-crank propulsion technique is less stressful than conventional hand-rim propulsion in T4–T6 paraplegic men (3), able-bodied women (4), and able-bodied nonwheelchair users and wheelchair sportsmen (5), and in field test wheelchair-dependant and able-bodied subjects (6). Although laboratory-based studies on stationary equipment enable careful standardization and help control the confounding variables, a more realistic approach of dynamic characteristics (stability, maneuverability) and environmental variation (temperature, humidity, ground surface, etc.) is needed to which the wheelchair users confront in their practical life. A field study was required in this context. Previous studies strongly support the fact that an arm-crank propulsion mechanism should be an alternative method of wheelchair propulsion (6,7). Until recently, no emphasis was placed in a practical way on the study of the impact of the arm-crank mechanism as a means of wheelchair ambulation. No liteature has been reviewed that compares the physiological response of the two propulsion systems simulating the actual locomotive condition and, moreover, no investigation was ever made with actual users. The energy cost and heart rate are the well-established parameters providing objective documentation for assessing the effectiveness of the ambulatory aids. The purpose of the present study was to compare the locomotor performance of the two propulsion systems. This study may be helpful in recommending the particular type of propulsion system regarding wheelchair ambulation in different locomotive conditions, according to the requirements of the users.

METHODS

Subjects

Thirty-four subjects with lower-limb disabilities, with history of traumatic paraplegia (spinal cord injury below T10 level) and poliomyelitis, volunteered to participate in this study. All were male, were wheelchair-dependent for their routine ambulation, and used their device regularly more than 6 yr. Initially, two separate frames were made for MWC (n=30) and APTWC (n=28) users. The subjects who were either very young <18 years) or very old (>50 years) were struck from the frame. Thus a revised frame containing 28 MWC users and 27 APTWC users was made. Then a random sample size of 17 was drawn for each group from the revised frames. The selected subjects of both groups were fairly homogenous physically and clinically. Particulars of the subjects are contained in **Table 1**. The subjects were screened to eliminate those with any symptoms of cardiovascular dysfunction, upper-limb pain or disability, or any sustaining complications secondary to wheelchair drive that could interfere with the interpretation of the experiment. Written consent was obtained from each subject before participation in the study.

The APTWC

The APTWC is a modified version of a wheelchair to a hand-propelled tricycle, built on a rigid frame. It consists of three bicycle wheels with pneumatic tires—one in the front and two at the rear. The diameter of the front wheel is comparatively smaller (24 in) than the diameter of the rear wheels (26 in). It consists of a steerable arm-crank unit; the flywheel of which is connected to the front

Table 1.
Physical characteristics and resting data of subjects.

MODE	Age (years)	Height (cm)	Weight (kg)	Years in wheelchair	Resting heart rate ($b.min^{-1}$)	Resting O_2 consumption ($ml.kg^{-1}.min^{-1}$)
MWC users Poliomyelitis (n=5) Paraplegia (n=12)	33.41 ±8.86 (18–47)	152.52 ±5.77 (146–164)	44.64 ±8.86 (34.5–61)	9.11 ±2.14 (6–14)	78.82 ±6.52 (68–94)	5.88 ±1.17 (7.86–4.25)
APTWC users Poliomyelitis (n=6) Paraplegia (n=11)	31.23 ±9.47 (18–46)	153.41 ±5.81 (143–164)	45.23 ±6.67 (35.1–56.2)	9.70 ±3.19 (6–13)	79.88 ±9.95 (62–108)	5.44 ±0.68 (7.61–4.64)

Values are mean, ± standard deviation (range).

wheel by a chain and sprocket mechanism mounted at the shoulder height of the rider. Friction-type coaster brakes are used at the front wheel and at the rear wheels, which permit a quick and effective application. The propulsion is brought about by arm cranking in asynchronous fashion. Steering is accomplished without interruption of arm cranking. Properly inflated pneumatic tires are used that provide necessary comfort to the rider. See **Table 2** and **Figures 1A** and **B**.

The MWC

The test MWC was one commonly available in the market. It is built on a folding frame, weighs 24 kg, with a rear-wheel diameter of 23 in., a rim diameter of 20 in., and caster diameter of 7 in., and has solid tires. See **Table 2** and **Figure 2**.

The Oxylog

The Oxylog (P.K. Morgan, Ltd.) is the portable oxygen-consumption meter used, because it is more convenient for fieldwork (8). The apparatus consists of a face mask fitted with expiratory and inspiratory valves and a turbine flow meter that is connected to the portable analyzer with a flexible hose. The face mask is fitted to the subject. The subject is allowed to breathe freely to measure inspiratory volume, and expired air is channeled to the analyzer and measures the difference between the partial pressure of oxygen in both the inspired and the expired air. The volume of oxygen consumption (in liters) per minute is displayed digitally. Before each experiment, the oxygen sensor was calibrated for atmospheric pO_2 and was checked before each test for standardization.

Variables

Propulsion speed ($m.min^{-1}$) was calculated by dividing the total distance covered by the subjects at their Free Chosen Speed (FCS) on the marked track by the time taken. Oxygen uptake (VO^2, $l.min^{-1}$) was obtained directly from the reading that was digitally displayed in the oxylog (the portable oxygen consumption meter), and heart rate ($b.min^{-1}$) was monitored with the help of a stopwatch during steady-state ambulation (5th minute of exercise). The energy cost per unit time (milliliter of oxygen consumed per kilogram of the body weight per minute)—the oxygen consumption (VO^2, $ml.kg^{-1}.min^{-1}$), per unit distance (the milliliter of oxygen consumed per kilogram of the body weight per meter)—the oxygen cost (VO_2, $ml.kg^{-1}.m^{-1}$), net locomotive energy cost (NLEC) (9) that expressed the energy cost per unit of body weight per unit distance traveled ($kcal.kg^{-1}.km^{-1}$), the physiological cost index (PCI) (10)—the ratio of heart rate to the speed of ambulation ($b.m^{-1}$), and the oxygen pulse[10] ($ml.kg^{-1}.b^{-1}$) were derived.

Test Course

Testing was conducted under conditions that closely approximated the customary locomotive conditions of the users. The track was chosen to simulate the

Table 2.
Criteria of manual wheelchair and arm-propelled three-wheeled chair.

	CRITERIA	MWC	APTWC
1	Propulsion mechanism	Hand rim	Arm crank
2	Mode of propulsion	Synchronous	Asynchronous
3	Required movements for propulsion	Complex and coordinated	Simple and natural
4	Mode of transportation	Indoor	Outdoor
5	Idling stroke	Yes	No
6	Good efficiency	No	Yes
7	Kinetic brake	No	Yes
8	Tire	Solid	Pneumatic
9	Weight	24 kg	42.5 kg
10	Turntable on the spot	Yes	No
11	Wheel diameter: front (F) rear (R)	F: 7 in., R: 23 in.	F: 24 in., R: 26 in.
12	Freewheel	Yes	No
13	Steering with additional parts	No	Controlled front-wheel steering
14	Back rest use	Less effective	More effective
15	Provision for gear change	No	Yes
16	Surface of propulsion	Smooth (concrete)	Rough (ground)
17	Cosmetic appearance	Impressive	Nonimpressive

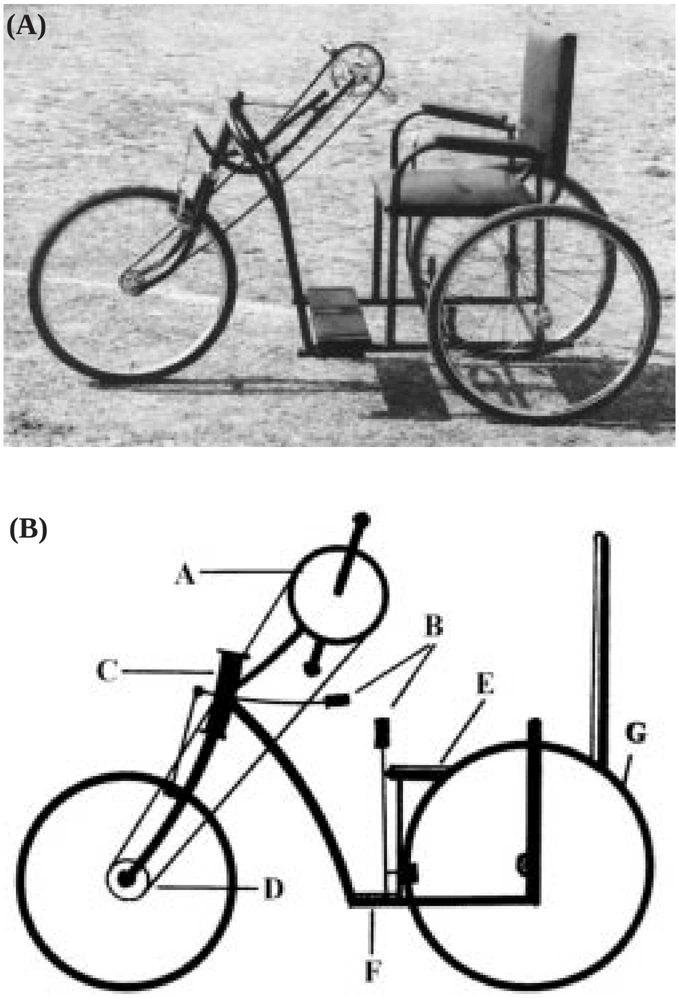

Figure 1.
(A) The arm-propelled three-wheeled chair. **(B)** Parts of the arm-propelled three-wheeled chair. A—the arm-crank unit, B—brakes, C—steering axis, D—sprocket of front wheel, E—seat, F—foot board, G—rear wheel.

environmental effect as encountered in the regular activities in practical life. The use of MWC is limited only to indoors and within a confined area with a round concrete track 62.85 m in circumference, and because APTWC is used in the rural areas to cover a long distance, the oval track on ground 358 m in circumference was considered in the present investigation. Two different types of tires were used—the solid tire in MWC and pneumatic tire in APTWC as available commercially. Hence, the nature of the tires was not standardized in both wheelchairs—the intention was to evaluate the strain felt by the two groups of users under existing systems. Pneumatic tire inflation pressure is of prime importance, and during the experiment, the inflation pressure was standardized within 86 psi. The exercise bouts were 5 min in duration because both groups could propel their wheelchairs for the said duration during their routine ambulation.

Figure 2.
The manual wheelchair.

Protocol

All participants attended an orientation session to familiarize themselves with the test procedures, and prior to testing, they were told the purpose of the experiment and the extent of their involvement. During the test course, it had been observed that the physiological variables of the first 3 min were increasing in nature and in the fourth and fifth minutes, the readings were fairly constant, indicating steady state. So the data were collected during the fifth minute of exercise. For collecting the baseline data of resting, each subject was instructed to sit quietly and comfortably for 15 min. The face mask-fitted oxylog was calibrated, oxygen uptake was measured for 5 consecutive minutes, and average heart rate was measured by timing 30 beats. After that, subjects of both groups (MWC and APTWC) were instructed to propel the test wheelchairs on their respective marked track at their comfortable speed (the FCS) in a steady pace for 5 min. The ambulatory data, i.e., speed, oxygen uptake, and peak heart rate sitting in wheelchairs and timing 10 beats with the subject sitting still in the wheelchairs, were measured immediately after the cessation of the assigned work. Immediately after the exercise period, the subjects rested.

Environment

Measurement of thermal environmental conditions prevailing during the course of the experiment showed the average values: dry bulb temperature 26.2±3.46 ºC, wet bulb temperature 20.6±2.91 ºC; and relative humidity 66.3±6.04 percent. The conditions were the same for all tests with regard to wind direction and speed.

Statistical Analysis

In the first phase of this study, the physical and physiological characteristics of the subjects of the two sample groups were statistically analyzed. Mean and standard deviations of these parameters were calculated, and then two sets of mean values were compared by using two-sample *t* test to determine the differences between these sample groups with respect to these two characteristics. Secondly, means and standard deviation of each of the experimental parameters, i.e., propulsion speed, heart rate, oxygen consumption, oxygen cost, PCI, NLEC, and oxygen pulse, for both groups were calculated. Finally, the equality of means between two groups for each parameter was tested with the use of the two-sample *t* test.

RESULTS

The physical characteristics of the participants in two groups, i.e., the MWC users and APTWC users, are summarized in **Table 1**. The two groups did not differ significantly with respect to the chosen physical and physiological parameters, e.g., age, height, weight, years in wheelchairs, resting heart rate, and oxygen consumption, as revealed from the result of the *t* test for two sample means tested at $p<0.05$. This suggests that the two groups, on an average, are relatively homogenous with respect to their physical characteristics and resting physiological condition. All the participants completed the test successfully and without any remarkable musculoskeletal, cardiorespiratory, or any other adverse experience. The orientation and motivation of the subjects were highly satisfactory.

The results of the present study in terms of speed and other physiological test parameters are summarized in **Table 3**. The propulsion speed of the APTWC users (134.82±14.46 m.min^{-1}) was found to be two and half times higher than that of the MWC users (56.4±8.7 m.min^{-1}).

Table 3.
Speed and energetics of MWC and APTWC in the present study.

Variables	MWC	APTWC	%	p<
1. Propulsion speed (m.min–1)	56.4 ±8.7	134.2 ±14.46	–58.16	0.001
2. Heart rate (b.min–1)	126.5 ±8.4	114.2 ±14.54	10.62	0.001
3. PCI (b.m–1)	0.86 ±0.11	0.25 ±0.06	244	0.001
4. Oxygen consumption (VO2, ml.kg–1.min–1)	13.5 ±3.38	8.67 ±1.07	50.17	0.001
5. Oxygen cost (VO2, ml.kg–1.m–1)	0.24 ±0.05	0.064 ±0.003	300	0.001
6. NLEC (kcal.kg–1.km–1)	0.66 ±0.22	0.11 ±0.03	500	0.001
7. Oxygen pulse (ml.kg–1.b–1)	0.10 ±0.02	0.08 ±0.01	25	0.001

Variables are mean, ± standard deviation, %Δ=% difference for MWC in reference to APTWC, p< indicates the level of statistical significance.

The ambulatory heart rate for MWC and APTWC group was 126.5±8.4 and 114.35±14.54 b.min^{-1}, respectively, and the percentage difference was 10.62. In case of PCI, the values were again 2.5 times lower in APTWC than that in the MWC group. The oxygen consumption was also higher by about 50 percent among MWC users as compared to the APTWC users, the average values being 13.5 and 8.67 ml.kg^{-1}.min^{-1}, respectively. The oxygen cost (VO_2, ml.kg^{-1}.m^{-1}) was three times more in the MWC group (0.24±0.05) than in the APTWC group (0.064±0.003). The two groups showed quite a remarkable difference with respect to NLEC, which showed a mean value 0.66 kcal.kg^{-1}.km^{-1} for the MWC users as compared to 0.11 kcal.kg^{-1}.km^{-1} for the APTWC users. Similarly, the oxygen pulse was also higher (0.10±0.02 ml.kg^{-1}.b^{-1}), albeit to a lesser extent, for the MWC group than that for the APTWC group (0.08±0.01 ml.kg^{-1}.b^{-1}). All these observed differences in the values of the two groups were found to be statistically significant and tested at a significance level of $p=0.001$.

DISCUSSION

Subjects and Wheelchairs

Notwithstanding the fact that the subjects of the two groups are fairly homogenous with respect to their physical characteristics and resting physiological conditions, the two groups might not have been strictly comparable if the same group of subjects were to use both propulsion systems. The two groups of subjects had to be selected as independent samples, because no individual could be found who used both propulsion systems. This was so because all the subjects chosen were habituated to a particular type of propulsion system. In future studies, this point may be taken care of while designing the study and choosing the subjects. The height and weight of the subjects were relatively lower considering the studies of the United States, because of ethnic difference. The average height and weight of the disabled Indians also have been reported earlier as 133.0±14.0 cm and 39.4±3.6 kg, respectively (11).

The design of MWC is like the conventionally used wheelchair in a single size that is produced in a large scale to reduce production cost. To accommodate the individuals, no arrangement of custom modification of the design was provided. The technical quality with respect to weight, stability, dimension, operation, and seating comfort is undoubtedly lower than the wheelchairs available in the United States. The wheelchair that was used in this study is heavier than the modern one, and from a physiological perspective, the performance of the lightweight wheelchairs is better (12). There is an increase in physical strain in MWC propulsion because of an increase of rolling resistance and internal losses. The plain bearing is still used today in the available wheelchairs instead of annular bearings with revolving ball or roller that are commonly used in the Western world. The plain bearing offers a high coefficient of friction that results in loss of internal energy (13). The internal loss occurs in the folding model, possibly by the deformation of the frame during exertion of forces in the push phase (12). The relatively smaller diameters of the front wheels have higher rolling resistance than the rear wheels of the MWC (13). The fluttering of casters also increases the rolling resistance in MWC (13). As the APTWC is propelled over the ground, the loss of energy takes places because the rolling resistance is higher on rough surface (ground) than smooth surface (concrete) (13). A properly inflated pneumatic tire (used in APTWC) has been reported to have smaller loss due to hysteresis than the solid tire and provides better shock absorption (14). Future study is needed to measure the coasting characteristics (rolling resistance, internal loses, and air drags) to optimize the mechanical efficiency of the APTWC.

Speed and Physiological Response of the Two Propulsion Systems

Propulsion speed may be considered as the basic clinical measurement of individual mobility in a wheelchair (15). The FCS has been used by different researchers to assess the locomotor performance of MWC in different conditions (16–18) and different systems of upper-body-powered vehicles (19). The FCS of the MWC in the present investigation is reported to be considerably lower than the research findings in the United States (16–18), but the energy cost documented by heart rate and oxygen consumption did not vary remarkably. This would indicate that in both studies, participants spent the same energy at FCS, but the basic inefficiency of the Indian study was the propulsion speed. This may be due to the poor technical quality of the wheelchairs and the skill and activity level of the MWC users, which were below par because they use the device regularly but for a short duration and in a sedentary way. Beyond the sedentary performance, they do not use the device for any adventurous and competitive use. It has been observed in the present study that higher propulsion speed of APTWC (139.04 percent more) than that of the MWC by the homogenous subjects reflects the higher efficiency of the arm-crank propulsion system.

The magnitude of physiological variables of the present investigation elicited in the arm-crank propulsion system was significantly lower than the hand-rim system. The ambulatory heart rate, energy consumption, and energy cost at FCS were consistently lower for the APTWC users, suggesting that the arm-crank propulsion system is physiologically less stressful. It provides effective use and involvement of larger muscle mass than the hand-rim system (6). During hand-rim propulsion, the smaller muscle mass has to work against a biomechanically disadvantageous propulsion system, and it is likely to cause an increase in heart rate and oxygen consumption. The involvement of larger muscle mass enables sustained locomotion in APTWC, and the small muscles are less subjected to localized fatigue because they are not intensely stressed. The effective use of larger muscle mass in arm and trunk contributes to generation of power required for arm-crank propulsion, and that provides a more efficient mode of ambulation than the MWC.

The physiological strain of the two propulsions could be assessed from the value of working heart rate in the “scale of heaviness” proposed by Christensen (20). According to the scale, the heart rate during MWC ambulation was 126.5 b.min^{-1}, which is considered as “heavy” work (range 125–150 b.min^{-1}), and the heart rate during APTWC ambulation was 114.35 b.min^{-1}, which is “moderate” work (range 100–125 b.min^{-1}). Moreover, from the report of an Indian study, Saha et al. (21), suggested that the heart rate of 110 b.min^{-1} is considered as a reasonable limit of long-term work, and the APTWC users could use the device for a long ride. According to Poulsen and Asmussen (22), the above-mentioned scale is less reliable, because it was based on able-bodied individuals rather than disabled and wheelchair-dependent persons, due to their lower physical work capacity. Future investigation is required to propose a reliable alternative scale for the disabled and wheelchair-dependent persons.

Glaser et al. (9) introduce a precise index that is expressed as energy cost locomotion per unit of body weight per unit of distance traveled—the NLEC—and it has been used to compare locomotive performance of WC on tile and carpet (9), locomotive economy for vehicle performance (19), and efficiency of arm-crank and hand-rim propulsion systems (6). It has been well documented that NLEC provides a useful index to ascertain the efficacy of propulsion and that it bears an inverse relationship with net mechanical efficiency; i.e., when NLEC is high, mechanical efficiency is low. The findings of the present investigation show the lower value of NLEC in APTWC propulsion proves the greater efficiency and locomotor economy than the MWC. McGregor (10) introduced PCI—the additional heart beat per unit distance traveled that indicates the fitness status of the individuals and the performance of ambulatory aids. The reported value of PCI during MWC ambulation in the present investigation is four times more than that of APTWC, indicating that the arm-crank propulsion system is more efficient than the hand-rim system. The PCI value of APTWC could be compared with the study of McGregor (10) where the PCI value of the said propulsion system is less than the value of PCI of walking of the normal subjects at self-preferred speed. Persons tend to have higher physical work capacity for arm cranking than hand-rim wheeling (23) and so the individuals using the arm-crank propulsion mechanism are able to accomplish their locomotive task in a relatively efficient manner compared to the hand-rim mechanism. The higher speed and lower physiological responses of the APTWC as compared to the MWC in actual locomotive condition by the regular users consistently supports the finding that arm-crank propulsion is suitable for outdoor use where sustained locomotion with higher speed and lower physiological demand is required.

Biomechanical Explanation

The physiological response revealed in the present study indicates that the arm-crank propulsion system is less demanding than the hand-rim propulsion system, and that could be related to more efficient propulsion biomechanics. The asynchronous mode of propulsion has been proven to be more efficient than the synchronous mode because of its lesser metabolic and cardiovascular demands, greater continuity of motion, advantageous utilization of the inherent neural pathways for reciprocal innervation of the contralateral muscle groups, and better balance and postural stability because of rotational movement of trunk (24). In the present study the APTWC propulsion is asynchronous in nature because the force is exerted simultaneously as pull and push with contralateral arms and the continuous application of force with no idle stroke utilizes the full energy expanded. In contrast the MWC propulsion is synchronous in nature when the applied force is intermittent—the discontinuous motion with idle recovery phase provides energy-wasteful movement—the energy is utilized during forward arm movement and wasted during backward movement. The upper-limb movement in the arm-crank propulsion system is simpler than the hand-rim system because additional coordinated and discontinuous movements of arm and substantial gripping force required in MWC propulsion. The more naturally oriented arm position and well-fitted grip (less static) to the arm-crank propulsion mechanism provides less strenuous coupling and results in maximal force generation. The gross mechanical efficiency of hand rim is lower than the arm-crank system (12,25,26); this may be due to ineffective application of the propulsive force that is less than optimal direction of the applied force, and the effectiveness is decreased with increase in speed (27). But in the case of the arm-crank system, the propulsive force is more optimally directed for higher efficiency. In APTWC the backrest provides support in generation of reaction forces in an effective direction requred for propulsion. The trunk and shoulder complex is also stabilized without any additional muscular effort and helps to generate the propulsive force effectively. During MWC propulsion, the forward leaning of the trunk during each push stroke is energy wasteful and also results in increase of pressure on caster wheel and rolling resistance which, in turn, increases energy demands (28).

Choice of Propulsion System

The study reveals that the MWC is less efficient, because of its higher physiological response and lower propulsion speed than the APTWC. In spite of its lower efficiency and higher metabolic cost, MWC is considered an all-purpose ambulatory device and is most commonly used, because of its excellent maneuverability within a confined space. According to Brubaker (29), "The hand rim is an effective propulsion interface which provides the user with maximum feedback and control. It is also the simplest and probably most reliable form of propulsion." The hand-rim propulsion system is suitable for indoor use where the short-duration and low-speed locomotive tasks are required, and is disadvantageous for outdoor use and unsuitable for rising road because of its reduction of speed during each idling stroke. The arm-crank propulsion technique's higher efficiency because of its biomechanical advantage and lower cardiopulmonary stress enables the users to long-distance ride with high speed and is appropriate for outdoor use. The APTWC is simple, affordable, strong enough to stand on unfriendly terrain, easily repairable by semiskilled labor, and has low maintenance cost. The arm-crank unit is in a disadvantageous ergonomic position; the unimpressive outlook of the device is cosmetically unacceptable and socially undesirable. The longer size limits its accessibility to various architectural and environmental situations.

Future research is needed for mechanical and ergonomic optimization of the wheelchair-users interface. The overall dimensions and weight of the device are to be reduced. Implementation of different gears will reduce the physical strain of the users. The influence of the anthropometric factors should also be considered.

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