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Validation of %VO2max Based on %VO2 Reserve for Exercise Prescription in Cerebral Palsy Patients

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ABSTRACT

Introduction & Objective: Exercise intensity is importance factor during physical activity. Thus, to ensure more targeted exercise intensity during cycling exercise, the relationship between exercise intensity indexes equations should be examined. This study examined the relationship between some exercise intensity indexes during cycling in spastic children. **Methods**: For this purpose, 25 adolescents with spastic cerebral palsy were completed graded exercise test on ergometery cycle. The severity of spastic of the patients was reported by the pediatric neurologist to be moderate to severe equivalent to 3 degrees in Ashworth Scale of Muscle Tone. Heart rate (HR) and oxygen uptake (VO2) were monitored in each stage of cycling test. Heart rate and VO2 data is used through test stages for calculating exercise intensity indices. A linear regression analysis used to determine the relationship between exercise intensity indices in each stage of exercise test. **Results**: we observed a positive correlation between %VO2max and %VO2reserve during cycling test. In the other hand, our results showed that $\%VO_{2Max}$ is correspond to $\%VO_{2Reserve}$ in each stage of test (r =0.99) and the correlation between %HRR with the other indexes (%VO2max and %VO2reserve) was lower. **Conclusion**: This study indicates that for prescription exercise training in spastic patients, prediction of %VO2max by %VO2R is better than by %HRR.

Keyword: Exercise intensity, cycling, spastic.

INTRODUCTION

Physiological benefits of exercise rely mainly on exercise intensity. The intensity of exercise is usually applied in two ways: relative and absolute. The absolute intensity is in fact a specific work load in a period such as the work load of 80 W on the ergometry bike (1). The relative intensity is specified by the relative physiological strain imposed on the body which is defined as a percentage of a maximum capacity such as maximum heart rate, maximal oxygen consumption or maximal exercise capacity (1). Scientific studies indicate that exercise intensity is the most important factor in continuity and improvement of cardiorespiratory fitness (2, 3, 4).

For prescription of exercise intensity in healthy people %HRR Method is widely used (5). Another method for prescribing exercise intensity is to use % VO_{2Max} Index (6). Research evidence reveal that depending on certain influencing factors these indices display different levels of work pressure applied on the body during activity; hence activity at any level (Percentage) of any of these indices may be expressed by other indices with a different proportion of the maximum percentage of that index (2) and this would cause confusion among sports trainers and rehabilitation activities in developing an appropriate training program that is effective and free of side effects. American College of Sports Medicine (ACSM) asserts that for prescribing exercise intensity in healthy subjects, %HRR and $\%VO_{2max}$ Indices both apply identical intensities (7). While the findings of Simmons on the relationship between exercise intensity indicators in particular, in patients with obstructive pulmonary disease are different from with the ACSM guidelines (8). The findings of other studies in this area are also heterogeneous and arbitrary (9, 10, 11). In alignment of %HRR and $\%VO_{2max}$ values, factors like age, body fitness level, the maximal or sub-maximal work intensities, cardiovascular status and environmental temperature are influential (2,3).

Recently some scientific resources have reported another method of formulating or prescribing exercise intensity particularly in rehabilitation activities of patients, designated as a percentage of reserve oxygen consumption $\%VO_{2\ Reserve} = \frac{VO2exercise - VO2rest}{VO2\max - VO2rest}$ (4, 6, 11, 12). In this regard, Swain et al suggest that during exercise on the ergometer bike, the relative values of % HRR are not equivalent to % VO_{2max} (13). There are no comprehensive findings as to the direct relationship between $\%VO_{2max}$ and $\%VO_2R$. But some scientific sources maintain that %HRR is equivalent to $\%VO_2R$ and not to $\%VO_{2max}$ (4, 12, 13, 14) and some others suggest the equivalence of $\%VO_{2max}$ to %HRR (16, 15) which seems to signify to some extent the difference between the two indices of $\%VO_{2max}$ and $\%VO_2R$ in different individuals.

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The point is whether one should act like healthy individuals as to the degree of alignment or lack of alignment of exercise intensity assessment indices with the decline in cardiovascular function or dysfunction of neuromuscular system due to certain diseases with prominent role on physical activity or rehabilitation exercises or; every type of disease follows a particular pattern depending on its impact on cardiovascular or neuromuscular or ... systems.

In this context, studies have indicated that taking medications by patients would lead to disorders in resting heart rate, exercise heart rate and the maximum heart rate (5) which results in difficulties in devising training programs with appropriate intensity based on %HRR and decreases the credibility of that index in prescribing the exercise intensity of sports-rehabilitation programs of patients. In this regard, new guidelines recommend using $\%VO_2R$ to prescribe the intensity of aerobic exercise in patients with heart diseases (17, 11). On the other hand, some findings point out that to prescribe exercise intensity in each disease, the relationship between %HRR and % VO2R should be evaluated separately (18). The findings of Wonisch report significant reduction in resting heart rate and maximum heart rate due to taking beta blockers in cardiovascular patients (5). Mezzani's study notes that for prescribing exercise intensity in patients with chronic heart disability, the values of %HRR and %VO2R are not identical and the correlation of these indices in rehabilitation activities of every illness should be examined separately (18). Colberg's findings suggest that due to taking certain drugs diabetic patients have higher resting heart rate and lower maximum heart rate than Healthy people (19). The relationship Sheri et al cite their findings and report an extraordinary linear relationship between $\%VO_{2Resreve}$ and %HRR in diabetic patients (12). Evidence shows that fitness levels in healthy subjects and patients, affect the relationship between exercise intensity indicators (8, 20, 21, 13). Further studies clearly indicate conflicting results in this regard among healthy populations and those with various diseases. Therefore, the role of the impacts of various diseases on these indices is significant enough to be deliberated and it seems that it is essential to determine the correlation of these indices in these diseases.

It seems that nervous system lesions and traumas in spastic patients can lead to reduced efficiency of cardiovascular and blood circulation systems and neuromuscular coordination especially during physical and sports-rehabilitation programs (22) and there are no comprehensive findings regarding the relationship between exercise intensity indices representing fundamental components in devising and prescribing exercise programs with appropriate and safe intensity in rehabilitation and occupational therapy programs not conducive to irreversible adverse effects such as fainting, nausea, seizures, epilepsy and ... in these patients. Thus considering the impact of the type of disease on the relationship between exercise intensity indices, the foremost aim of this study is to compare the relationships and to determine the exercise intensity indices ($\%VO_{2max}$, %HRR, $\%VO_{2Reserve}$) in patients with spastic diplegic cerebral palsy in order to prescribe safe and efficient sports-rehabilitation programs based on any of these indices.

MATERIALS AND METHODS

The statistical population of this study includes spastic diplegic cerebral palsy children. Subjects included 25 Patients Spastic boys (aged 12±2) with permanent disability history who participated in this research voluntarily (with parental consent form) and with the approval of specialist physician and occupational therapists. The severity of spastic of the patients was reported by the pediatric neurologist to be moderate to severe equivalent to 3 degrees in Ashworth Scale of Muscle Tone (23). Written consent was obtained from each patient parent's after the experimental procedures and possible risks and benefits were clearly explained. Subjects were banned from any serious exercise for a period of 24 hours before the test, and started avoiding eating any food one hour before the test. After familiarizing the participants with activity on the ergometer bike, McMaster ergometry protocol (24) as a children specific test in the average ambient temperature of 21 Degree Celsius and 64% humidity on a Tunturi ergometry bike (Type E 604, Made in Finland).

In McMaster Test, the subjects start with about 2 Minute on the ergometry cycle to warm up; then the main test that includes 4 successive 2-minute stages is implemented. The subject should first pedal the first 2-minute stage (12.5 Watts) in accordance with the instructions of the protocol and in the last 15 seconds his heart rate is recorded by a telemetry device. Other 2-minute stages of the test continue with in the same manner with the difference that the work load is increased by a certain level (25 Watts) compared to the preceding stage and this continues until the fourth stage. If a subject feels weak or exhausted at any stage of the test, the test is interrupted and the heart rate of that stage will be recorded as the ultimate heart rate of the test. Heart rate and VO2 data is used through test stages for calculating exercise intensity indices. Although, the best way to measure VO_{2max} is the direct method but due to high costs and complexity of this method and lack of equipment VO_{2max} was measured indirectly using the Multi-stage / Diagram method (25). After calculating exercise intensity indices ($\%VO_{2max}$, %HRR, $\%VO_{2Reserve}$), the correlation between of these indicators was determine by linear regression analysis in SPSS environment and the regression model and linear regression equation between each pair of indicators of exercise intensity was determined in the subjects.

RESEARCH RESULTS

The results of multiple regression analysis indicated that relationship between the two indices $\%VO_{2Reserve}$ and $\%VO_{2Max}$ is linear in the subjects, with slight differences with the line identity (R = 0.99). The regression equation between the two indices is: ($\%VO2_{reserve} = 1.023 \times \%VO2_{max} - 3.99$) (Fig 1).

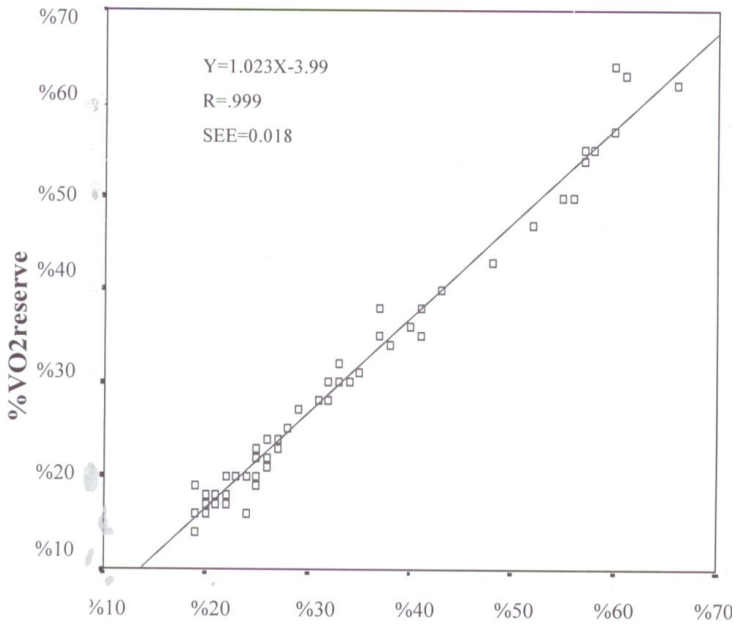

Fig 1: The regression pattern between %VO2reserve and %VO2max during cycle test in studied subjects

On the other hand, the correlation between the two indices of $\%VO_{2Reserve}$ and %HRR has a linear pattern, but the degree of correlation between these two indicators is far less than the two indices ($\%VO_{2Reserve}$ and $\%VO_{2Max}$) (R = 0.91). It can be said that at any level of ergometry activity the rate of the exercise intensity in terms of %HRR was significantly higher than $\%VO_{2Reserve}$. The regression equation between the two indices is: ($\%VO2_{reserve} = 1.055 \times \%HRR - 18$). The research findings show that correlation between exercise intensity scales ($\%VO_{2Max}$ and %HRR and R=0.92) is similar to the correlation of ($\%VO_{2Reserve}$ and %HRR) and also indicate that under sub-maximal pedaling activity, the values of exercise intensity based on %HRR were significantly higher than those of $\%VO_{2Max}$ (Fig 2). The regression equation between the two indices is: ($\%VO2_{max} = 1.0\ 34 \times \%HRR - 13.8$).

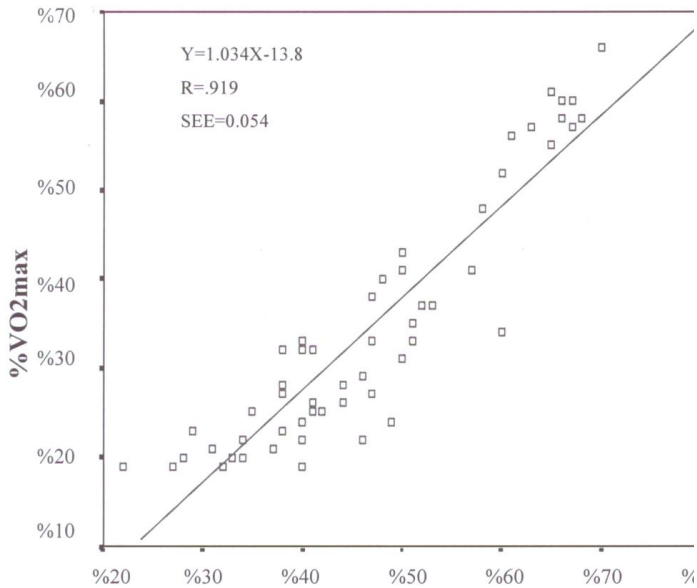

Fig 1: The regression pattern between %VO2reserve and %VO2max during cycle test in studied subjects

DISCUSSION AND CONCLUSION

In 1957 Karvonen devised a method of assessing exercise intensity in which the target heart rate was estimated by a certain percentage of difference between resting heart rate and maximum heart rate (26). He called this technique Heart Rate Reserve (%HRR) which widely used for prescribing training programs in sports-rehabilitation exercises in healthy subjects and patients (4). On the other hand, in predicting the exercise intensity, ACSM recognizes %HRR and $\%VO_{2Max}$ as being equivalent which is also supported by some researchers in sports sciences and gradually balance between these two exercise intensity indicators was used in most scientific studies. Wen's study on patients with chronic obstructive pulmonary disease supports this theory (15). Some recent studies, however, maintain that during activity on the ergometer bike %HRR values are equivalent to those of $\%VO_{2Max}$ but %HRR values matched those of $\%VO_{2Reserve}$ (27). The findings of other studies on healthy subjects and various diseases also suggest a different similarity pattern between each of the exercise intensity indicators depending on fitness level, cardiovascular fitness and their type of disease to which reference was made in the introduction of this research (2, 4 , 9 , 10 , 14 , 18).

The results of this study indicate that in spastic patients at any level of activity the two indices of $\%VO_{2Max}$ and $\%VO_{2Reserve}$ are consistent with a slight difference and by increasing the activity level from each test stage to the following stage the value of this difference decreases slightly. Pointed Such an overlap suggests that in these patients the two indicators show the same degree of intensity at each level of activity, and their regression predictor line matches the line of identity once the slight difference is ignored and the difference of %HRR with these two indicators is significant which is consistent with the findings of Miller et al on obese men and women (28). This process is probably due to effects of the nervous system disorders of these patients on the cardiovascular system.

Hui's findings on healthy children indicate the correlation coefficient of r = 0.95 between the two indicators of %HRR and $\%VO2_{reserve}$ (16). On the other hand, David has also reported the correlation coefficient between these two indicators as r = 0.99 (4) as shown in the following diagram (Diagram 4). Stanley too reports the correlation coefficient between the two indicators of %HRR and $\%VO2_{max}$ as r = 0.95 (16) which are inconsistent with the findings of this research on patients with cerebral palsy.

Overall, The results of this study reveals that besides physiological development transformations phenomenon and confounding factors, it is possible that cerebral palsy to some extent disturbs the overlap of linear pattern of these scales; as the findings of this research on children with CP suggest that $\%VO_{2Max}$ and $\%VO_{2Reserve}$ are consistent at any given level of intensity of ergometry activity. With an overall review of the studies, it can be concluded that the type of disease and the consumed drugs significantly impact the relationship between exercise intensity indices depending on their effect on cardiovascular and neuromuscular systems (6, 12, 14) and devising an appropriate training program requires understanding the relationships between these exercise intensity indices. By obtaining the pattern of relationship between these indices using the said equations, especially in sports-rehabilitation programs on those who suffer from some sort of motor disability, it would be possible to devise a safe and efficient training program and developing continuous exercises with appropriate intensity based on each of these indicators would not only lead to no serious and irreparable damage in these patients, but it would even be useful.

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