



Acute effects of different exercises on hemodynamic responses and fatigue in Duchenne muscular dystrophy

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Research Article

Purpose: The aim of the study was to investigate the acute effects of different types of exercises on hemodynamic responses and fatigue in Duchenne muscular dystrophy (DMD).
Methods: Thirty DMD subjects of an early stage were included in the study. One of the three different types of exercises was applied in only one exercise session. These were three-minute stair climbing, 40-minutes cycling and 40-minutes stretching-strengthening and aerobic exercises for the upper and lower extremities accompanied by a physiotherapist. Acute exercise responses including the heart rate, oxygen saturation, muscle strength responses, fatigue and timed-performances were assessed just before and after the exercises. A questionnaire was applied to assess how perceived fatigue reflected to daily activity performance after exercises.
Results: The heart rate after climbing stairs and physiotherapy program were increased while expressed fatigue levels after all three exercises were increased ($p<0.05$). After the cycling and physiotherapy program, duration of standing up was increased ($p<0.05$). There was an increase in muscle strength after climbing stairs and decrease after cycling while there was no significant difference after physiotherapy ($p<0.05$). No performance reduction in daily activities after exercises was declared by subjects. **Conclusion:** Physiotherapy exercises under the supervision of a physiotherapist may be more effective and less tiring compared to other exercises in DMD patients.

Key words: Duchenne muscular dystrophy, Muscle strength, Exercise, Hemodynamics.

Duchenne musküler distrofide farklı egzersizlerin hemodinamik cevaplar ve yorgunluk üzerine akut etkileri

Amaç: Çalışmanın amacı, Duchenne musküler distrofi (DMD)'de farklı egzersiz tiplerinin hemodinamik yanıt ve yorgunluk üzerine akut etkilerinin araştırılmasıydı. **Yöntem:** Çalışmaya erken dönemdeki 30 DMD'li çocuk dahil edildi. Çocuklara seçilen üç farklı tipte egzersizden biri yalnızca tek bir seans uygulandı. Bunlar üç dakika merdiven çıkıp-inme, 40 dakika bisiklet sürme ve 40 dakika fizyoterapist eşliğinde üst ve alt ekstremiteler için germe-kuvvetlendirme-aerobik egzersizleri içeren bir program idi. Kalp hızı, oksijen saturasyonu, kas kuvveti ve yorgunluk değerlendirmeleri ile süreli performans testlerini içeren egzersizin akut etkilerini gösteren ölçümler egzersizlerden önce ve sonra yapıldı. Çocuklarda egzersiz sonrası oluşan yorgunluğun günlük aktivite performansına yansımaları anket yardımı ile değerlendirildi. **Sonuçlar:** Merdiven çıkıp-inme ve fizyoterapi egzersizleri sonrasında kalp hızının arttığı bulundu ($p<0.05$). İfade edilen yorgunluk seviyesi ise her üç egzersiz sonrasında artış gösterdi ($p<0.05$). Oturmadan ayağa kalkma süresinin, bisiklet ve fizyoterapi egzersizleri sonrasında arttığı bulundu ($p<0.05$). Kas kuvvet cevabının merdiven çıkıp-inme sonrasında arttığı, bisiklet egzersizi sonrasında azaldığı ve fizyoterapi programından sonra değişmediği belirlendi ($p<0.05$). Egzersiz sonrası günlük aktivitelerindeki performansları değişmedi. **Tartışma:** Fizyoterapist denetiminde yapılan fizyoterapi egzersizlerinin, erken dönem DMD hastalarında hemen egzersiz sonrası değerlendirilen hemodinamik yanıtlar ve kas kuvveti göz önüne alındığında daha etkili ve daha az yorucu olabileceği düşünüldü.

Anahtar kelimeler: Duchenne musküler distrofi, Kas kuvveti, Egzersiz, Hemodinami.

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Duchenne muscular dystrophy (DMD) is the most common muscular dystrophy form in childhood worldwide with an incidence of 1 in every 3500 live births.¹ The most common symptoms in early stages are unwilling to walk, delayed walking, walking on the tips of the toes, a stiff ankle and excessive fatigue.² The severity of the fatigue in neuromuscular diseases is closely related to the severity of various functional impairments followed by muscle weakness in daily life.

Kalkman et al have found that decreased muscle strength causes the reduction of physical activity level in patients with neuromuscular diseases.³ Patients with decreased physical activity level have been shown to have increased severity of perceived fatigue even after short-term and low intensity physical activity.³ Authors have been reported that increased fatigue level causes the decreased physical activity level in a blind circle. Authors emphasized the importance of non-exhausting physical activity on fatigue and encouragement to increase the physical activity level instead of decreasing to cope with fatigue in neuromuscular diseases.³ It is important to plan an appropriate exercise type and severity according to the functional level of child without any exhaustion during the exercise session. Many studies showed the long term effects of exercises on physical functions like gait, muscle strength and performance after a period of training sessions in neuromuscular diseases.^{4,5} However, acute effects of exercises on hemodynamic responses and fatigue of DMD patients have not been reported yet. The aim of our study was to determine the acute effects of different types of exercises on hemodynamic responses and fatigue in DMD patients.

METHODS

Subjects:

A total of 30 DMD patients at Stage 1 or 2 according to the Brooke Functional Classification,⁶ who were directed to our physiotherapy unit by a pediatric neurologist, were recruited in the study within a three months

period. Children who were still ambulant (6-11 years of age) were included in the study. The children who had not previously undergone a surgery from one of their lower extremities, who did not have contractures over 20 degrees in lower extremities (especially the ankle joint), who did not have any other neurological or systemic disease besides DMD and who had not got any cognitive problem were included in the study. The power of the study was found to be 60% with 5% Type 1 error.

Measurements:

The demographic characteristics of the children including age, height and weight were recorded. The heart rate and oxygen saturation were measured with a pulse oximeter (POX, Model: KPIS-01, Steoul, Korea). The Pictorial Variant of the Children's Effort Rating Table scale which was developed to evaluate fatigue levels of children subjectively with the pictures showing the severity of the fatigue due to effort was used in the study.⁷ The questionnaire was used after translation into Turkish by the authors. The children were asked to rate their fatigue status between 0 and 10.

Muscle strength measurements were used as an objective method to evaluate the acute response of the muscles to fatigue before and after the exercises. The strength test was performed on the hip flexor, extensor, internal and external rotator muscles, knee flexor and extensors and ankle dorsi flexor and plantar flexor muscles using a hand-held dynamometer (Type: CT 3001 Citec, C.I.T. Technics B.V., The Netherlands,) at the manual muscle test positions.^{8,9} The measurements were repeated three times for each muscle and the mean measurement recorded as kilograms (kg).

Timed performance tests have been accepted to be a valid and reliable method to evaluate the functional status of children with DMD or to assess the results of a treatment approach.¹⁰ Tests were used to determine the effects of applied exercises on fatigue. The time elapsed during 10-meter walking and standing up after long sitting position on a mat were measured in seconds and recorded.¹¹ Children who needed help to stand up after long sitting on the mat were allowed to hold

from their parents hands, from a chair or a step to take support.

After the first assessment of the children as described above, 23 of the 30 children were accepted to ride a stationary bike during 40 minutes. The MOTomed Viva2 of Reck Medizintechnik (RECK-Technik GmbH and Co., Germany) was chosen for cycling.¹² This bicycle enables active, active-assistive and passive exercising of the patients. Bicycle also gives a feedback to child as 'you are cycling without any motor power' when he cycles actively and gives a report after the exercise about the active duration of cycling. The moderate difficulty levels, approximately 50% of maximal heart rate, were selected individual-specific according to the pre-exercise evaluations of children. The time required to ride the bike was determined by the fact that a physiotherapy session lasts 40 minutes on average. The children actively completed the 40-minute bicycle exercise on the back-supported sitting position following an active/active-assistive warm-up period of approximately five minutes.⁴

Design:

Ten of the 30 children underwent a 40-minutes physiotherapy program. The program was including; (1) stretching of M. Gastrosoleus, Hamstrings and hip flexors for 10 minutes, with 10 repetition and waiting 10 seconds in each repetition for warming up, (2) strengthening exercises for upper and lower extremities by using weights, three sets, 10 repetition in each set and one minute resting interval between sets during 20 minutes, (3) Recreational activities for general mobilization of both upper and lower extremities including games (playing basketball or tennis etc.) in an exercising room according to the interest of the child as appropriate for his functional status during 10 minutes. These exercises were applied during 40 minutes in one session, two or three days after cycling to the children who were also done cycling or stair climbing.¹³

Twelve of the 30 children accepted to go up and down a 5-step standard stairs in a timed manner for three minutes (stair climbing test) without giving any time to rest during the test. The time period (three minutes) for stair climbing was

decided after a pilot study applied on early stage DMD patients. In pilot study, children declared increased level of perceived fatigue approximately at the 5th minute of climbing the stair when encouraged not to stop and be as fast as possible they could. Therefore, three minutes was determined as middle intensity when children were encouraged to climb the stairs as fast as they could.

The children were undertaken these three types of exercises in different three days with two or three day intervals to let them to fully rest. All of the evaluations were conducted at the same day of each exercise applications. Children were not allowed to rest just after the exercise session before post-exercise evaluations. The whole evaluations including heart rate and oxygen saturation and lower extremity muscle strength measurements, perceived fatigue level, observational gait analysis and walking on a powdered ground to evaluate other characteristics of the gait and timed performance tests were performed just before and after the exercises by the same physiotherapist.

A survey, using telephone interview, was performed the next day of each exercise to evaluate whether the post-exercise fatigue affected the children in performing daily activities in the same day of exercise applications. The questions of the survey are presented in Table 1. The responses of children or their parents were evaluated.

The study was approved by Hacettepe University Ethic Committee (26.02.2009, LUT 09/15).

Statistical Analysis:

Wilcoxon Signed Rank Test was used to compare the evaluation results of the children before and after the stair climbing, cycling and physiotherapy exercise. A p value of <0.05 was used for statistical significance.¹⁴

RESULTS

The mean age, weight, and height of the children were 7.87 ± 1.45 years, 23.78 ± 4.05 kg, and 120.83 ± 9.39 cm, respectively (N=30).

Hemodynamic responses: We only found a statistically significant difference with the baseline values in the heart rates measured after the stair climbing and physiotherapy exercises ($p < 0.05$) (Table 2). There was not any statistically difference in heart rate measurements before and after cycling ($p > 0.05$). We found no statistically significant difference with the baseline values of the oxygen saturation values measured after all three exercise types ($p > 0.05$) (Table 2).

Fatigue levels and muscle strength measurements: We found a statistically significant increase between the fatigue levels of the children after each of the three exercise procedures compared to the baseline value ($p < 0.05$). The changes in fatigue levels after all three exercise types were shown in Table 2. There was a significant increase in the knee and total lower extremity muscle strength following climbing the stairs while there was a decrease following the bicycle exercise ($p < 0.05$) (Table 2).

Timed performance tests: We found a statistically significant increase in the time to get up from a sitting position following the 10 m walking and getting up from long sitting position timed performance tests after bicycle and physiotherapy exercises ($p < 0.05$) (Table 2).

The surveys administered to the children to evaluate the effects of post-exercise fatigue on the daily activities, did not produce any results indicating a negative effect on performing daily activities.

DISCUSSION

The main purpose of rehabilitation in early-stage DMD patient is preserving ambulation as long as possible. Exercise programs combined with active-passive joint range of motion, stretching, strengthening, and pulmonary and aerobic exercises are thought to be best-suited programs for this purpose in early stage DMD patients.^{5,15-21} We therefore used 40-minute physiotherapy sessions including stretching, strengthening, functional and aerobic exercises with a 40-minute cycling and 3-minute stairs climbing to investigate the acute effects of these

different exercise modalities on fatigue and hemodynamic responses in children with early-stage DMD.

Other articles on the effects of long-term exercises on fatigue and muscle strength jointly declare that maximal exercise in patients with DMD causes loss of muscle strength due to muscle breakdown and physiological fatigue together with a sensation of exhaustion.^{5,15-22} It was therefore debated in the past whether patients with neuromuscular disease should be kept away excessive exercise in rehabilitation programs as it could lead to "overuse weakness" and muscle fiber loss. However, it has been proven that aerobic exercise of large muscle groups with adequate intensity and duration (30 minutes at 50-85% of maximum oxygen consumption) leads to appropriate physiological responses over time in the heart, peripheral circulation and musculoskeletal system.²³ We found that we had exercised our patients at 53.3% of the maximum heart rate during heart rate measurements immediately after the stairs climbing test and 49.5% after bicycle exercise while 58.5%, submaximal heart rate for neuromuscular patients, of physiotherapy exercises. This indicates that it is possible to develop appropriate cardiopulmonary responses more effectively in time with physiotherapy exercises including stretching, strengthening functional and aerobic exercises without exhaustion which are used together under the supervising of a physiotherapist in patients with early-stage DMD as well.

Fatigue is a general symptom that leads to exercise intolerance in many neuromuscular disorders.³ Clinical studies have shown that excessive and repetitive muscle activity can lead to decreased power production by the muscle with fatigue.²⁴ Our patients reported an increase in the sensation of fatigue following all three exercise procedures. However, there was a decrease in knee and total lower extremity muscle power responses only following the cycling while there was an increase after the stairs climbing test and no change in lower extremity muscle power after physiotherapy exercises. We believed that the decreased knee muscle strength and related

Table 1. The survey that implemented the next day of each exercises.

Did your child need to rest more than other days after exercise when you turn back to home?	(Yes-No)
Did your child have difficulties in the activities such as feeding, dressing, bathing and going to the toilette more than other days after the exercise?	(Yes-No)
Did your child need to rest on the home way – if you walk to home- more than other days after exercise?	(Yes-No)
Did your child complaint from muscle-joint pain more than other days after exercises?	(Yes-No)
Did your child show any reluctance or difficulty in attending the games with his friends more than other days after exercise?	(Yes-No)

Table 2. Comparison of baseline values with the values after stair climbing, cycling, and physiotherapy exercises.

	Baseline	After stair climbing (N=12)		After cycling (N=23)		After physiotherapy (N=10)	
	X±SD	X±SD		X±SD		X±SD	
Heart rate (bpm)	103.2±14.3	113.5±18.3	**	105.8±12.2	*	124.1±19.6	**
Oxygen saturation (%)	97.7±2.0	97.6±1.1	*	97.5±1.8	*	94.9±6.6	*
Fatigue (VAS, 0-10 cm)	2.1±1.8	8.1±1.9	**	8.1±2.3	**	7.3±2.1	**
Strength of knee muscles (kg)	69.1±27.8	77.2±14.1	**	53.7±24.9	**	76.3±32.1	*
Total muscle strength (kg)	73.4±26.9	81.2±13.4	**	61.6±28.2	**	83.4±31.8	*
Time of sit to stand (sec)	5.3±3.8	4,91±3	*	7.5±6.1	**	22.2±6.5	*

* p>0.05, ** p<0.05. VAS: Visual analog scale.

decreased lower extremity muscle strength after cycling was due to the fact that the bicycle exercise took place while sitting on a seat with back support and therefore resulted in loading especially on the quadriceps and hamstring muscles.

The increase in knee and total lower extremity muscle strength responses after the 3- minute stairs climbing test may be the result of the warming up effect of this test on lower extremity muscles. The lack of any change in lower extremity muscle strength response after physiotherapy exercises indicates that the use of both upper and lower extremities and trunk results in less loading of lower extremity muscles and that this exercise creates general fatigue in the body. In

contrast to cycling without resting intervals, we made sure that the exercises were performed in a more controlled manner by supervising of a physiotherapist during the physiotherapy sessions to ensure alternative work-out of the upper and lower extremity muscles with a specific number of repetitions (maximum 10) and short resting intervals. We therefore believe that the muscle fatigue that develops is at a level that will not affect the patient's daily functions. Our patients did not report any decrease in performance when they returned to their daily life following the exercises. This shows that the fatigue that develops just after all three exercises can be eliminated following an adequate recovery period

and that it will not affect the performance and capacity related to their daily activities.

Lindeman et al found a strong correlation between the quadriceps muscle strength and timed performance tests in their study which was performed on a group of different neuromuscular patients.²⁵ Therefore; the increased duration of one of the timed performance test-standing up from long sitting position-following cycling is thought to be due to the decreased strength response of the lower extremity muscles as a result of the excessive loading on quadriceps and hamstring muscles. It may be more effective that children rest a short time while cycling in rehabilitation sessions when these findings considered.

After the 3-minute stairs test, as an acute response to the exercise, we find an increase in the knee and total lower extremity muscle strength while the fatigue complaint is existing and the lack of a difference in the timed performance test results. This indicates that short-term warm-up before exercise sessions may increase muscular performance during exercise in patients with early-stage DMD just as in healthy subjects.

This study shows that aerobic exercise, strengthening and stretching exercises in children with early-stage DMD does not lead to excessive fatigue and loss of function at a level that would affect their daily living activities just after the exercises. Although using the bicycle exercise during physiotherapy sessions has practical benefits, the load it creates on certain muscle groups may cause excessive fatigue during the exercise. The most important result of this study was the observation that administering physiotherapy exercises with certain repetitions and resting intervals and active monitoring by a physiotherapist may prevent the excessive fatigue localized on certain muscles.

The limitations of our study are that the various laboratory tests such as blood lactic acid measurement and muscle biopsy that could have been used in determining the fatigue levels and short-term response to exercise of the children who took part in the exercise sessions could not be used because of technical inadequacies.

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