Evaluation of lactic acid transfer to contralateral hand with two different type muscle contraction

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Abstract

This study is conducted with the aim of investigating the effect of two kind of muscle contraction on generating lactic acid in a limb and investigating the effect of that on the amount of lactic acid in the contralateral limb. In favor of the study objective, the subjects were university students who are not athlete. The subjects consists of 12 students male between 20-22 years old 21.8± 4.12 (who has not a regular sport history over the past two years. First of all, the amount of lactic acid in active and non-active hand at the rest time before exercise was measured. Then in two separate steps the subjects’ analysis was carried out. In the first and second stage (next day) 70% of maximum muscle strength was estimated and the first stage by choosing the suitable weight, the action of holding at the angle of 90 degree with isometric contraction and in the second stage the action of elbows bent and open with isotonic contraction to the extent of fatigue was carried out. Immediately after completion of the aforesaid activities the amount of lactic acid in active and non-active hand was measured and registered. The data were analyzed by using correlation t-test and the result of research showed that after isometric contraction more lactate is accumulated in the active muscles than isotonic contraction and also in the Statistical test there was no significant difference in the above case. By considering that the measurement of lactic acid in the non-active limb was done immediately after the completion of training, the results indicate that the transfer of lactate in the blood to the non-active limb is not that much which can affect the limb. Results from this study do not approve the effects of accumulated lactic acid on active limb and the transfer of that to the non-active limb and it’s inconsistent with the theory of transfer of power and muscular endurance from trained limb to untrained limb (cross transfer theory).

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Introduction
Fatigue caused by physical activity will depend on several factors. One of the most important factors of muscle fatigue and the inability to continue physical activity is accumulation of lactic acid in the blood and muscles which wear down the possibility of muscle activity to continue. Many coaches and athletes routinely perceive lactic acid, or more specifically lactate, as a dead end waste product that is completely unfavorable to all athletic performance. This assumption however, may longer be considered accurate so much so that it has been labeled the mythology of lactic acid (Brooks et al., 1996). Over the past 35 years, evidence has mounted against this idea (Gladden, 1996; Brooks, 2001).

The best evidence seems to suggest that oxygen availability is only one of several factors that cause an increase in muscle and blood lactate during submaximal exercise. In fact, lactic acid can be formed anytime glycolysis takes place regardless of the presence or absence of oxygen and is even produced at rest (Wilmore et al., 2005). During intense exercise, muscle and blood lactate can rise to very high levels (Fitts, 2003). This accumulation above resting levels represents the balance of production and removal. It says nothing about whether accumulation is due to an increased rate of production or decreased rate of removal, or both. Similarly, if lactate concentrations in the blood do not rise above resting levels during or immediately following exercise, it also infers nothing about lactate or lactic acid production during that activity. It may be that lactic acid production is several times higher than at rest but that it is matched by its removal showing no net increase (Donovan et al., 1983). A common misinterpretation is that blood lactate or even lactic acid, has a direct detrimental effect on muscle performance. However, most researchers agree that any negative effect on performance associated with blood lactate accumulation is due to an increase in hydrogen ions. When lactic acid dissociates it forms lactate and hydrogen ions - which leads to an increase in acidity. So it is not accurate to blame either lactate or lactic acid for having a direct negative impact on muscular performance. The increase in hydrogen ions and subsequent acidity of the internal environment is called acidosis. It is thought to have an unfavorable effect on muscle contraction (Fitts, 2003). At rest the normal range for blood lactate is 0.5 - 2.2 mmol per litre (Gollnick et al., 1986; Mc Gee et al., 1992). It is thought that complete exhaustion occurs somewhere in the range of 20 - 25 mmol/L for most individuals (Mainwood et al., 1985). Although values greater than 30 mmol/L have been recorded (Hermansen et al., 1972). Blood lactate concentrations peak about 5 minutes after the cessation of intense exercise (assuming cessation is due to exhaustion from acidosis) (Gollnick et al., 1986). The delay is attributed to the time required to buffer and transport lactic acid from the tissue to the blood (Juel, 1988). A return to pre-exercise levels of blood lactate usually occurs within an hour and light activity during the post-exercise period has been shown to accelerate this clearance (Gollnick et al., 1986; Hermansen et al., 1972; Freund et al., 1978).
Training can also increase the rate of lactate clearance in both aerobically and anaerobically trained athletes compared to untrained individuals (Gollnick et al., 1986; McMillan et al., 1993; Pierce et al., 1987). Interestingly, noted that trained individuals generated higher levels of blood lactate at the point of failure compared to untrained subjects when exercising intensely (squats) (Stone et al. 1987). The time and amount of work they completed, unsurprisingly, was greater in the trained group. This seems to suggest that training may induce greater tolerance to lactate accumulation and it may also add weight to the argument that lactate serves to delay acidosis and fatigue. At any absolute workload (i.e., when both groups were lifting the same weight) the trained group had lower levels of blood lactate. This indicates that training induced adaptations include a lower blood lactate concentration at any given workload and higher blood lactate concentration during maximal exercise (Gollnick et al., 1986; Sutton et al., 1987; Jacobs, 1986). The anaerobic or lactate threshold is based on the point at which blood lactate abruptly accumulates. It can be used as a prediction for race performance and to prescribe training intensity. Now, there is a question that persons who have physical activity with a special limb (for example doing an activity just with right hand) and by considering the created condition for right hand whether opposite limb (left hand) is also affected by this activity? Or can the lactic acid accumulation will also be occurred in this limb by the blood stream or not? The fact that train the muscles of a limb (corresponding to one side of the body) can improve muscle strength endurance and even learning the motor skills on the other side (opposite side) has attracted the interest and attention of the researchers in the field of physical education, sport medicine, physical therapy, neurology, and rehabilitation. Even nowadays, the reason for this cross transfer is not completely recognized. Many researchers that study the theoretical basis of this phenomenon believe that the explanation for this transfer is related to the field of neuroscience. For example, it has been suggested that this phenomenon is caused by the release of nerve stimulators which 70 to 85 percent of that shift from nerve fibers of premotor area of the contralateral cortex and the 15 to 30 remained percent transmit to the dynamic member from the nerve fibers of the same part, While still there are some debate about the most effective way to develop a cross (symmetrical) transmission, power, endurance and skill. Researchers agree that by using the principle of overload this transition occurs effectively. Transfer of some factors such as muscles strength from a limb to opposite limb by excursioning with weight have put under observation by many researchers and the results show that it was hoped that someone who unable to perform activity with a limb due to damage, constant exercises with opposite limb could prevent atrophy and loss of muscle strength. On the other hand constant exercises could increase tolerance to lactic acid and delay fatigue. But in relation with transfer of lactic acid from one limb to the opposite side and its effects on fatigue in the contralateral limb there is vagueness and this is matter because the outcomes of research in this field could convey useful information about how cross transmission through blood flows to opposed limb to researchers, educators and enthusiasts. The notion that contralateral limb exercise might produce long-term benefits, a phenomenon called ‘cross-education’ or ‘cross-transfer’, is actually over a century old,(Scripture et al, 1894) although the mechanism remains unclear.

Early physical rehabilitation techniques frequently used bilateral reciprocal exercise for spastic hemiplegic cerebral palsy patients (Fay, 1954). In healthy individuals, 8 weeks of isometric exercise training activation of cortical neurons related to contralateral can increase the strength of the contralateral elbow flexors by as much as 25 % (Moritani et al., 1979). This cross transfer of strength phenomenon is actually quite effective in both the upper limbs (Hellebrandt et al., 1951; Shields et al., 1999) and the lowerlimbs(Kannus et al., 1992; Shima et al., 2002).The increase in maximal force produced by contralateral resistance exercise training is generally greater following training using dynamic rather than static, isometric contractions(Meyers, 1967; Rasch et al.,1957).Muscle lengthening exercise is particularly effective,(Anson et al., 1993) resulting
in strength gains in the contralateral limb as high as 77% (Hortobagyi et al., 1997) although these eccentric contractions may also produce muscle soreness (Clarkson et al., 1988; Dedrick et al., 1990). Thus, it is clear that increases in muscular force can be obtained by resistance exercise training involving the contralateral limb.

**Materials and methods**

To answer the research question, the effects of both isometric and isotonic contraction on lactic acid accumulation in active limb and transferring to non-active limb were examined and finally, a comparison of lactic acid in non-active limb before and after exercise was examined too. For this study subjects were selected to investigate the effect of isometric and isotonic muscle contractions on accumulation of lactic acid in active and non-active hand. The subjects were selected from university students that who are not athlete (without any specific disease history). They were 12 voluntary male students in between 20-22 years old who has not a regular sport history over the past two years and all were right-handed. Before starting the test, the subject’s blood lactic acid level was measured at rest to ensure participants did not have activity before the test. Then each of the individuals did the isometric contraction as much as they became fatigue. The procedure of performing isometric contraction was as follows: dumbbells with a weight equal to 70% of maximum strength of the elbow flexor muscles for each subjects, was selected and at the extend of fatigue hold the weight at a 90-degrees angle of elbow to arm for 45 seconds (isometric contraction) and this was repeated with a rest period of 15 seconds to reach the total duration of 2 minutes. Immediately after exercise, lactic acid levels were measured in active and passive hand. In the second stage in another day the second step test was conducted. At first blood lactic acid level were measured at rest and then to 70% weight of maximum strength of the elbow flexor was chose. Subjects were asked to open and close the elbow with maximum effort (isotonic contraction), and in fatigue condition, 15 seconds of rest was given to muscles. This was repeated up to 2 minutes and immediately lactic acid levels were measured in active and passive hand.

**Results**

This study have shown that intense activity with maximum intensity and speed for 1 to 3 minutes can causes lactic acid accumulation in blood and muscle and so this will cause fatigue and the inability to continue the activity. Accumulated lactic acid in active muscle will gradually excrete in the several processes and after several hours after exercise muscles lactic acid levels will reduce significantly. However due to blood flow in the muscles produced lactic acid may be spread from active limb to the contralateral limb. The result of one correlated t-test showed that the subjects average lactic acid in resting time in active and non-active limb were 2.33 and 2.22 respectively and the mean of subjects lactic acid after isometric contraction after completion of activity in active hand were 14.93 and in non-active hand were 2.51. The obtained results of correlated t-test of lactic acid accumulation between two type of isometric and isotonic contraction in lactic acid generation in active and non-active hand(α =0.01) showed a significant difference.(Fig:1). Mean of subjects’ lactic acid before test in active and non-active hand were 2.38 and 2.29 respectively and after isotonic contraction after activity impletion in active hand were 13.52 and in non-active hand were 3.30. Paired correlated t-test showed no significant difference (α =0.01) in lactic acid accumulation in right hand or active hand and left hand or non-active hand. (Fig:2). By considering the average rate of lactic acid accumulation after isometric and isotonic contraction, in active limb in order were 2.38 in rest time, 14.93 after isometric contraction and 13.52 after isotonic contraction. The result obtained from correlated t-test showed no significant difference (α =0.01) in lactic acid accumulation in right hand or active hand.The amount of lactic acid accumulation after isometric and isotonic contraction in order were 2.29 in rest time, 2.51 after isometric contraction and 3.3 after isotonic contraction, The result obtained from correlated t-test showed no significant difference (α
in lactic acid accumulation in left hand or non-active hand.

**Fig. 1.** The comparison lactic acid level in rest time and after isometric contraction in active and non-active hand.

**Fig. 2.** The comparison lactic acid level in rest time and after isotonic contraction in active and non-active hand.

**Discussion**

Magnus examined cross-transmission during the 4 weeks of training in the assessment of shoulder strength, size and muscle activity on the trained an untrained side. The results showed that cross transmission of the immobilized limb after elbow extension exercise was more effective and also power exercise in size and strength was more useful for active member rather than sedentary member (Magnus et al., 2010). Bezerra examined the isometric contraction of the right leg and assert that increase of power without hypertrophy in the untrained leg confirms cross-transfer theory (Bezerra et al., 2009).

Limited studies (Arai et al., 2001; Papandreou et al., 2007) have reported the effect of cross exercise in patients following knee reconstruction. Papandreou et al. have shown that cross eccentric exercise has been proved to be a useful mechanism in strengthening the quadriceps muscle on the ACL reconstructed knee by training the uninjured knee, at knee angles at 45° and 90° of knee motion at a sequence of 3 d/w, in the early rehabilitation phase of ACL reconstruction (Papandreou et al., 2007). CE (cross eccentric) is referred to the contralateral limb, by increasing strength in the homologous muscle of the untrained limb, without directly involving the latter in the motor activity (Zhou, 2000). Several neural mechanisms have been proposed for CE including diffusion of impulses between hemispheres, coactivation via bilateral corticospinal pathways, postural stabilization and the cerebral cortex theory which has been referred to as the most dominant mechanism. It is explained by the theory that during the voluntary contraction of a muscle on the trained side is produced a facilitation effect on the same motor point in the opposite side of the cerebral cortex (Zhou, 2000, Kristeva et al., 1991).

This is also explained anatomically by the fact that 10% of the corticospinal fibers enter in the lateral and anterior corticospinal tract of the trained side, whereas the remaining fibres cross to the opposite side of it through diffusion of impulses. Benefits of CE have been well established on quadriceps strength improvement in healthy subjects (Zhou, 2000; Hortobagyi et al., 1997). As far as the type of CE is concerned, eccentric exercise has been found to be superior to isometric and concentric exercise (Hortobagyi et al., 1997, Hortobagyi et al., 1996; Hortobagyi et al., 1996) and has had the greatest effect on quadriceps strength improvement accounting for the greater increases in eccentric and isometric forces (Hortobagyi et al., 1997; Hortobagyi et al., 1996; Hortobagyi et al., 1999). However, an intraspinal mechanism is probably more likely to mediate CE especially in studies that observed remarkably greater CE using eccentric contractions (Zhou, 2000; Housh et al., 1996; Weir et al 1995). In addition, it would be suggested that eccentric contractions are associated with unique motor unique activation strategies by the nervous system and that the process of inducing CE may be different for training with concentric and isometric contractions (Hortobagyi et al., 1997; Hortobagyi et al., 1996; LaStayo et al., 2003).
Shima announced that cross-transmission and increased power in symmetry limb could be depend on central nervous system factors and is not limited to lack of exercise period (Shima et al., 2002). Moritani conducted a study based on muscles hypertrophy during 8 weeks isotonic strength training. The results showed that increase of hypertrophy has seen after 3 to 5 weeks and also the flexor muscle of opposite hand has confirmed the cross-transfer theory and proved that this exercise could stimulate the nervous system at different levels and increase the maximum muscle activity (Moritani et al., 1975). By considering the research results can be stated that this physiological phenomenon is something that happens certainly and the increase of strength and endurance in untrained limb is a result of increase in the aforesaid factors in the trained member. Many studies have reported transfer exclusively from the dominant to the nondominant hand and vice versa, and there are also studies that show transfer in both directions or in neither. For instance, in different paradigms, researchers have uncovered skills that transfer from the dominant to the nondominant arm (Ammons, 1958; Gordon et al., 1994; Halsband, 1992; Parlow et al., 1991; Teixeira, 2000) and from the nondominant to the dominant arm (Hicks, 1974; Parlow et al., 1990; Taylor et al., 1980) as well as skills that transfer both directions (Morton et al., 2001) and skills that do not transfer in either direction (Baizer et al., 1999; Kitazawa et al., 1997; Rand et al., 1998; Teixeira, 1993). Consistent with this variety of results, there have also been reports of one direction of transfer for some aspects of a task and another direction of transfer for other aspects of the same task (Parlow et al., 1989; Sainburg et al., 2002; Thut et al., 1996). This implies that patterns of generalization strongly depend on the task. The result of research showed that after isometric contraction more lactic acid accumulated in active muscles in comparison with isotonic contraction.

Statistical test showed there was a significant difference in above case. This result is consistent with the other conducted same research. The obtained result may be because of that in isometric contractions due to reduction in blood flow in muscle and shortage of oxygen the possibility of using anaerobic glycolysis system for energy supplying will increase and this will lead to a substantial lactate accumulation in muscles. On the other hand the accumulation of lactic acid in non-active limb is significantly less than active limb in both isometric and isotonic contraction. The result of statistical test showed a significant difference in this case. This confirmed the hypothesis which said that in non-active limb there is no effect of fatigue due to lactic acid accumulation. By considering that the measurement of lactic acid was done immediately after the training, the obtained result indicate that transfer of lactic acid in the blood to non-active limb is not that much which can affect the limb. Also subjects after isometric and isotonic exercises completion did not feeling tiredness in non-active limb, therefore the statistical results obtained in this study will be approved. The result of this study doesn’t confirm the effect of lactic acid accumulation in the active limb and the transfer of that to contralateral hand and its inconsistent with the research has done in association with transfer of strength and muscle endurance from trained limb to untrained limb.

The reason of this inconsistency might be that performing special training for strength and endurance show its effects in long time and followed by these workouts a gradual increase in strength and endurance happens to non-active limb but in connection with the transfer of lactic acid from active to non-active limb should be mentioned that this research has been carried out following a grueling training session. Also the cross transfer of strength and muscular endurance (to non-active limb) is performed by neural processes too but in concerning with lactic acid cross transfer, blood flow can be effective, thus may be could say the reason of difference is the method of transfer between two subjects. By considering that the same research field has not seen and this research is conducted for the first time therefore to definitive comment and answer
to this question that will the accumulated lactic acid transfer occur from active hand to contralateral hand after a high intensity activity and can cause fatigue in non-active limb, will need more research in this area.

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