MUSCULOSKELETAL INJURIES, PHYSICAL FITNESS, AND BENEFITS OF SPORT SCIENCE APPLICATIONS IN THAILAND BOATING ATHLETES

Seekaow Churproong

Received: March 29, 2013; Revised: June 21, 2013; Accepted: June 21, 2013

Abstract

Data of the Thai national boating team athletes were collected at a Suranaree University of Technology camp prior to the 26th SEA Games, 2011. A holistic approach and integrated care were provided for the whole team. From 109 questionnaires, there is presented: 1) the tendency towards musculoskeletal injuries in the athletes, it being found that shoulder and back injuries have a 34 and 63 odds ratio of risk estimate, respectively, in those occurring prior to the camp and those occurring during the first month of the camp; 2) the comparison of lactate thresholds at pre- and post-training found 6 athletes (4 injured and 2 uninjured) with an improvement; considering the fixed anaerobic threshold of 4 mmol·l^{-1} lactate between 8 injured and 8 non-injured rowers compared with the Mann-Whitney U test found no statistically significant difference; after the experiment, the doctor prescribed various methods of therapy and encouraged athletes to be more interested in rehabilitation in order to perform on an equal basis with non-injured athletes; and 3) a comparison of the opinions of the boating athletes in each type of boat concerning the benefit of sport science applications during the SUT camp compiled from 90 questionnaires which were returned. It was found that the topics of building more strength, creating more motivation, perceiving more systematic training, and getting specialized care were statistically significantly different depending on each boat type. These outcomes were notified to the Rowing-Canoeing Association of Thailand (RCAT) with a view to extending the use of the sport science model to new areas. The application of sport science is a small cog in a very large wheel where the players and the coaches are the key people.

Keywords: **Thai national boating team athletes, musculoskeletal injuries, lactate threshold, sport science applications, integrated care**

Introduction

Sport science is a discipline that studies the application of scientific principles and techniques with the aim of improving sporting performance. It should be applied in all sport teams in all processes through training and competition. In many countries, the

School of Medicine, Institute of Medicine, Suranaree University of Technology, 111 University Avenue, Mueang District, Nakhon Ratchasima 30000, Thailand, Tel: 66-4422-3950; Fax: 66-4422-3920; E-mail: seekaow@sut.ac.th

application of sport science and medicine is routinely practiced but there is not quite so much application in Thailand. Fortunately, the Rowing and Canoeing Association of Thailand (RCAT) affiliated with Suranaree University of Technology (SUT) to work with the Thai national Team boat athletes in developing a system of sport science application for all the athletes at the SUT camp. Eight gold medals, 7 silver medals, and 11 bronze medals were won at the 26th SEA Game in Indonesia, 2011 by the Thai national team boat athletes who trained at the SUT camp. This paper focused on the role of a family physician, acting like a sports physician, with an emphasis on a holistic approach to injuries. The definition of holistic care is a care composed of physical, psychological, social, and spiritual parts (McWhinney, 1997). Separating the job into 3 sections it was possible to present all parts of the integrated care consisting of health promotion, injury prevention, and therapy and rehabilitation. The aims of the research were as follows: 1) screening of injuries by questionnaires in which athletes declared their musculoskeletal injuries in specific anatomical sites both prior to and during the first month of the camp; 2) a comparison of the injured rowers' lactate threshold (LT) with the non-injured rowers reassured them that, if there is good compliance and a discipline to rehabilitation, injuries will be gone and the athletes can show their best performances; and 3) in order to assess the outcomes with levels of satisfaction when the RCAT applied sport science in the SUT camp, questionnaires were sent to all athletes after camp. Finally, all outcomes were sent to the RCAT for consideration as to whether this system should be modified for further camps to set a new model for training in Thailand.

A sports injury presents an obstacle for athletes during their training and affects their performances. Standardized assessment of sports injuries provides important epidemiological information and also directions for injury prevention and causes. The summer Olympic Games 2008 resulted in 1055 injuries, an incidence of 96.1 injuries per 1000 registered athletes (there were a total of 10977 registered athletes). Half of the injuries (49.6%) were found to keep the athlete from competing or training. The most prevalent diagnosis was overuse (22%). The risk of incurring an injury was found to be lowest for synchronized swimming, diving, swimming, fencing, canoeing/kayaking, rowing, and sailing (Junge *et al.*, 2009). Even though rowing was found to have the lowest risk of injury, we found that 22.22% of 109 Thai national boating athletes had health problems and nearly half (45.83%) of the health problems were musculoskeletal injuries. It is known that when athletes are injured, their mental and physical powers will decline in spite of encouragement by the team physician. Thus, the physical fitness of these musculoskeletal injured athletes was evaluated by focusing on the lactate test. Actually, physical fitness assessment has a lot of parameters but the lactate test was chosen because, when athletes have injuries, they can train for endurance capacity by cross training exercises. LTs indicate the point of fatigue when athletes have exercised for long periods of time or have increased their speed or workloads. Lactic acid is produced in anaerobic glycolysis which takes up to 3 min, after which it is converted to pyruvic acid in aerobic respiration, a long process which could take hours (Seeley *et al.*, 2011). The lactate test is performed via blood from the earlobe or fingertip while exercising. Basically, the resting lactate test should indicate less than 4 mmol/L. Therefore, the LT (anaerobic threshold) should exceed 4 mmol/L, depending on the cardio-respiratory fitness of the athlete. The anaerobic threshold paces are shown in Figure 1. Training slightly below the LT will shift the threshold to the right so that the athlete is able to compete at higher intensities for longer periods of time (Hill, 2010). The velocity or intensity of training has a similar O_2 consumption ($L.min^{-1}$).

In addition, heart rate (HR) responses to exercise, or HR variability, has been associated with a lower mortality rate and found to be affected by both age and sex. Heart rate monitors have thus become widely used for training in a variety of sports to determine the exercise intensity of a training session or race. The relationship between the HR and oxygen uptake (VO_2) has been used to predict maximal oxygen uptake (VO_{2max}) relying on several assumptions. It has been shown that the results could deviate up to 20% from the true value. The HR-VO_2 relationship is also used to estimate energy expenditure in field conditions. The relationship between the HR and other parameters is also used to predict and monitor an individual's training status which could be influenced by numerous factors. The duration of the training program may be one of the factors responsible for the HR-VO_2 relationship. Furthermore, factors such as dehydration and ambient temperature could also have a profound effect (Achten and Jeukendrup, 2003). The whole data determined by the LT is measured by the marker workload and equivalent HR parameters. It is necessary to take into account a ‘‘needs analysis’’ and assessment of the sport in question as well as the individual athlete, as for example, the application of weight training in accordance with the current dose-response relationship for exercise prescription among athletes (Peterson *et al*., 2004).

Team physicians in a sports medicine role should maintain good working relationships, especially with coaches in charge of the training programs. Maintaining open paths of communication between all members of the team seems to be the biggest key to success and an optimal way to avoid confusion and pitfalls. This requires more than just skill in diagnosis and treatment of musculoskeletal conditions, but also an active interest in sport, and a willingness to explore treatment of other health problems with a holistic approach and integrated care. Nevertheless, only 4% of all musculoskeletal injuries ultimately require some form of surgical intervention. In the greater number of instances, a well-trained specialist in rimary care in sports medicine may be sufficient (Fu *et al*., 2007; Madden *et al*., 2010). In addition, family physicians do more than just general therapy by adding integrated care and a holistic approach. Family physician applied the patient center methods with individual plan, sequentially.

The remaining key issue is the application of sport science to athletes by employing cross training exercises to maintain cardiovascular and respiration system fitness. For example, some rowers with knee injuries should not engage in running as they might further exacerbate the injuries, but rather

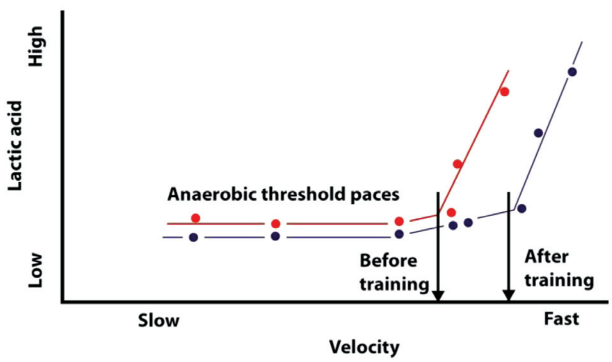

Figure 1. Lactate threshold shift to right after training. The slow velocity of training is similar with low O_2 consumption ($L.min^{-1}$) and the fast velocity of training is similar with high O_2 consumption ($L.min^{-1}$) (adapted from: Hill, 2010)

should do swimming or bicycling. Cross training is different from interval training, since cross training is practiced in many activities to achieve fitness goals. The variety aids in the decrease of boredom and the repetitive use of the same muscle group, which may cause musculoskeletal injuries (Dodd and Powers, 2009). Thus, the hypothesis of this research is that the application of sport science through a sports medicine team may help the injured athletes and the whole athletic team to recognize the self-care system for capacity improvement.

Materials and Methods

Section I

The study engaged the entire Thai national boating team of 109 athletes who were selected by the RCAT for the SUT camp. The athletes competed in 3 types of boats: 1) there were 32 rowing athletes, with 23 men and 9 women; 2) 52 traditional boat athletes, with 26 men and 26 women; and 3) 25 kayak-canoeing athletes, with 17 men and 8 women. Before distributing the questionnaires for the first screening of recorded injuries, the objective was explained to the athletes: to discover the solutions to help them improve their physical condition in time for competition. The questionnaire was chosen so that the athletes would feel free to reply about their injuries.. The analytical study was used for summarizing and analyzing the data from the questionnaires by frequency, Chi-square test, and risk estimation. This statistic was indicated in rate and odd ratios informed their specific anatomical area of injuries between prior and during SUT camp. Next, the family physician rechecked and confirmed their injuries by questioning them and by physical examination. Then individual treatment and rehabilitation programs were planned for further management and complete recovery. The preliminary data was shown to the coaches and managers of the RCAT so that they could recognize the injuries that come from training and how to deal with them.

Section II

From the beginning, the testing was planned for 3 boat types: the traditional boat, kayak-canoeing, and rowing. Unfortunately, just before the second test, the traditional boat and kayak-canoeing teams left the SUT camp. The former team found the SUT camp site too limited for training. A kayak-canoeing regatta was held on exactly the same day as the test, thus the team could not participate. There were limitations in testing too and the RCAT did not have a standard ergometer for testing; so, the tests were put into the exclusion criteria. Thus, the test was conducted only on the rowing athletes. As a competitive sport, rowing dates back several hundred years, and was one of the original sports in the modern Olympic Games. We studied a selective sample of 16 rowers who performed with a standard ergometer for testing and who stayed for the entire program. They underwent testing twice after they were aware of their musculoskeletal injuries. The first testing consisted of the lactate test followed by a 3-month course of therapy until they were better. At the end of the therapy, the second lactate test was conducted. Finally, we used purposive sampling to recruit 8 athletes with musculoskeletal injuries from the rowing Team (7 men and 1 woman), as well as the uninjured group (again, 7 men and 1 woman). After giving their informed consent, 15-50 microliters of blood was collected from the fingertip via a safe T Pro Plus needle and tested with Roche Accutrend Lactate. This was followed by the step test protocol (5×4 min) on the Concept II rowing machine ergometer. For any given load, there is an energy cost known as the metabolic equivalent of task (MET). An increase of 25 watts on the indoor rowing machine was approximately equivalent to 1 MET and brought about an increase in oxygen consumption of 3.5 ml/kg/min. The step test used for this test had a display in terms of pace/500 m and approximately related to 25 watts/1 MET increments. The test consisted of 5×4 min intervals, each rowed at a consistent 500 m pace. The load was increased at each step. The first 4 min step was set at the level allowing the athletes to complete the 4 min comfortably with no signs of distress or exhaustion and allowed them 30 sec rest between each step for the lactate test. The last 4 min step would require the athlete to row with extreme power. All the information was recorded at each step, including heart rate with a Bion A400 heart rate monitor, workloads on the rowing machine ergometer, and lactate concentrations (Atkinson and Atkinson, 2006).

However, the protocol was adjusted for lactate testing convenience to have a 1 minute rest. The lactate test was performed a total of 6 times, including the resting lactate test at the beginning. The coaches set default workloads on the rowing machine ergometer according to the competency of each athlete before an increase of 25 watts at every step. All steps were closely supervised by a physician with a view to any health problems, exhaustion, and even accidents when the LT was tested. The Lactate–Software for Calculating Blood Lactate Endurance markers was used to analyze the LTs (Newell *et al.*, 2005). During nearly the last 50 years, the blood lactate curve and LTs have become important in the diagnosis of endurance performance. Even though a total of 25 different LT concepts were located, all concepts were divided into 3 categories. Several authors use fixed blood lactate concentrations during incremental exercise to assess endurance performance (category 1). Other LT concepts aim at detecting the first rise in blood lactate concentrations above baseline levels (category 2). The third category consists of threshold concepts that aim at detecting either the maximal lactate steady state or a rapid/distinct change in the inclination of the blood lactate curve (category 3). Many scientific studies have dealt with LT concepts, their value in assessing endurance performance, or in prescribing exercise intensities in endurance training (Faude *et al.*, 2009). Comparison of prolonged exercise tests at the individual anaerobic threshold (IAT) and the fixed anaerobic threshold of 4 $mmol{\cdot}l^{-1}$ lactate (ATC) found that, in 15 of 19 rowers, the IAT corresponded to lower workloads than the ATC. In these cases, prolonged exercise tests at the ATC showed gradual increases in lactate concentrations (Stegmann and Kindermann, 1982). So, the ATC was chosen to be used in this study due to rowing involving prolonged exercise tests and following the example of several authors. The second testi followed the same process as the first when injured athletes were treated and rehabilitated for 3 months. The therapy was composed of a variety of treatments and rehabilitation strategies depending on the athlete's symptoms, including acupuncture for 1 athlete, physical therapy and ultrasound for 6, and massage for 1 athlete. Each treatment was done 2 times every week for at least a half an hour of the physical therapy, acupuncture, and Thai massage. All cases were given cross training exercises as well as strengthening and stretching exercises. If the athletes had injuries, they did cross training exercises instead of warm up and to replace the type of exercise that the coaches ordered them to do. As a part of the stretching and strengthening of muscles, the athletes were given additional routine schedules of exercise to be done at home by themselves.

The baseline characteristics of the athletes in both groups were compared. In particular, the experimental study compared the median difference of the LT in both parameters, The marker workload lactate threshold (watts) and equivalent HR lactate threshold (beats per minute (bpm)). The Thai national rowing team athletes were tested twice both the athletes with musculoskeletal injuries (the injured athletes) and those with no musculoskeletal injuries (the non-injured athletes), and the results were analyzed with the Mann-Whitney U test. $P < 0.05$ was considered to be statistically significant in all comparisons.

Section III

All 109 athletes were surveyed for their opinions after the therapy and sport science applications during the SUT camp via the same questionnaire which, when tested for reliability of the statistics, showed it to be 0.867 using Cronbach's alpha. Only 90 of the athletes returned the questionnaires, and these were included in the criteria. Those who did not return the questionnaires were excluded from the criteria. The results of this survey focused on the injured athletes during the camp and the method of therapy that they used. The analytical study was used for multiple comparisons in each boat type about the athletes' opinions on the role of sport science applications, especially sports medicine approached with one-way Anova and Scheffe comparisons; a 95% confidence interval (CI) was estimated.

Every section was approved by the ethics committee with all subjects submitting both written and verbal informed consents. All statistical tests were performed by the SPSS program.

Results and Discussion

Section I

The musculoskeletal injuries and correlation of injuries both prior to and during the first month of the training camp of the Thai national boating team athletes were considered. Sixty six (60.55%) of the athletes were male and 43 (39.45%) were female, with ages ranging from 19 to 23 (21.42 $\pm$ 5.54). The duration of practice prior to the training camp was not more than 4 months. The demographic data showed the rate of musculoskeletal injuries: it was found that 9 (8.26%) athletes only experienced injuries prior to the training camp; 25 (22.94%) athletes experienced injuries during the training camp in the first month; and 33 (30.28%) athletes experienced injuries in both periods of the training camp, respectively. Forty two (38.53%) athletes never had injuries in either of the periods of the training camp (Table 1). The rate of injuries increased when the athletes practiced during the training camp in the first month. Moreover, the practice sessions of 35 (32.10%) athletes were affected by their injuries. This result indicated that the athletes were not well prepared for training in the first month. Muscle preparation for training should be composed of stretching and strengthening for physical fitness (Ratamess, 2012). Nevertheless, previous research has not indicated that if injuries prior to training camp were brought to attention there could be established a plan to prevent further musculoskeletal injuries according to the specific anatomical areas of

Table 1 The demographic data of the number of injured and non-injured athletes of each boat type and period of injuries at this camp

Background of athletes	Number of injuries (persons)							
	Boat type							
	Rowing		Traditional boat		Kayak-canoeing		All	
	Yes (M/F)	No (M/F)	Yes (M/F)	No (M/F)	Yes (M/F)	No (M/F)	Yes (M/F)	No (M/F)
Period of injuries								
- prior to camp	3 (2/1)	21 (14/7)	1 (1/0)	32 (19/13)	5 (5/0)	14 (8/6)	9 (8/1)	67 (41/26)
- during camp (first month)	6 (6/0)	18 (10/8)	13 (8/5)	20 (12/8)	6 (2/4)	13 (11/2)	25 (16/9)	51 (33/18)
- both periods	8 (7/1)	15 (8/7)	19 (6/13)	19 (11/8)	6 (4/2)	8 (6/2)	33 (17/16)	42 (25/17)

the musculoskeletal system by strength training (ST) and stretching sessions to treat and rehabilitate the injured athletes. Athletes would benefit in general as well as in the area of injury prevention. Thus, this information would be necessary in order to make accurate diagnosis and treatment protocols for these injuries, which were mainly chronic in nature (Rumball *et al*., 2005). Focusing on specific anatomical areas of injuries, 27.16% of the injuries were found in the shoulder area and 19.75% were found in the area of the back. Chi-square and risk estimation which were used for analyzing the association of injuries that were incurred prior to and during the first month of the training camp found that the association was significant ($P < 0.01$), i.e. the overall chance of injuries increased by 6.64 times (OR = 6.64, 95% CI = 2.73 – 16.16). When focusing on the specific anatomical sites of the injuries, the probability in repeating back injuries increased by 63 times (OR = 63.00, 95% CI = 5.75 – 690.37) and repeating shoulder injuries increased by 34 times (OR = 34.00, 95% CI = 4.91 – 235.61). Other anatomical sites of injuries, i.e. wrist, arm, and knee had no significant differences (Table 2).

The anatomical areas of injury depended on the action of musculoskeletal movement during practice in each type of boat, correlating with previous research. Rowing injuries arose primarily from the overuse of the related muscles, with common musculoskeletal problems occurring in the lower back, ribs, shoulder, wrist, and knee, or other more sport-specific problems. The injury rate was directly related to the volume of training and technique

Table 2. Association of injuries prior to camp and during the first month of the camp of the Thai national boating team athletes

Number (%) of injured athletes at each specific anatomic site		Chi-square	OR (95% CI)	*P* value*
prior to camp	**during camp**			
Shoulder 14(41.18%)	Neck 4(11.76%)	0.025	0.436(0.041-4.689)	0.874
	Shoulder 15(44.12%)	**13.958**	**34.000** (4.907-235.605)	**0.000****
	Back 10(29.41%)	1.531	0.250(0.044-1.430)	0.216
	Wrist 2(5.88%)	0.000	1.462(0.084-25.525)	1.000
	Waist 3(8.82%)	0.000	0.692(0.057-8.470)	1.000
	Knee 7(20.59%)	0.109	0.500(0.082-3.046)	0.742
	Ankle 3(8.82%)	0.000	0.692(0.057-8.470)	1.000
Back 12(35.30%)	Neck 4(11.76%)	1.469	7.000(0.639-76.708)	0.225
	Shoulder 15(44.12%)	0.000	0.857(0.207-3.552)	1.000
	Back 10(29.41%)	**15.326**	**63.000**(5.746-691.373)	**0.000****
	Knee 7(20.59%)	0.742	0.242(0.026-2.304)	0.389
	Ankle 3(8.82%)	0.000	0.909(0.074-11.194)	1.000
Arm 2(5.88%)	Neck 4(11.76%)	0.359	9.667(0.474-197.279)	0.549
	Shoulder 15(44.12%)	0.000	1.286(0.074-22.416)	1.000
	Back 10(29.41%)	0.000	2.556(0.144-45.386)	1.000
Wrist 2(5.88%)	Back 10(29.41%)	0.000	2.556(0.144-45.386)	1.000
Knee 6(17.65%)	Shoulder 15(44.12%)	1.080	0.200(0.021-1.938)	0.299
	Back 10(29.41%)	0.068	0.422(0.043-4.165)	0.794

*Note: (**p < 0.01)*

(Karlson, 2000; Hosea and Hannafin, 2012). It was found that up to 25% of all reported rowing injuries are in the low back region during the rowing stroke and the catch position. The maximum stroke length, contributing to an increased risk of back injury and fatigue of the spinal extensor muscles, has been proposed to result in a decreased ability of the lumbar spine to resist further flexion forces acting on the spine during drive. However, muscle strain is the most common back injury with pain in the low back, involving the erector spinae muscles and/or the sacroiliac joint region. But lumbar disc herniation is also very common with compressive loads. Shoulder injuries, which are due to the catch phase of the stroke, have, as the most common pathology, tight latissimus dorsi and weak rotator cuff muscles and common technical errors are mostly the causes (Rumball and Lebrun, 2010). However, muscle preparation does not only include stretching for injury prevention but also training should include strengthening for the athletes as well. Consistent with the prevention of acute muscular strains is the implication of adequate pre-season screening of flexibility and strength balances in major joints (knee, shoulder, and ankle). Flexibility, strength, endurance, and proprioception should be assessed also. Adequate agonist/antagonist ratios for strength and flexibility should be attained for major muscle groups and muscles must be strengthened in the mode in which they are used functionally. Warm-up and stretching before activity are recommended and ST should be used as well (Buono *et al.*, 2013).

Section II

The baseline characteristics of the Thai national rowing team athletes for the 2 groups (musculoskeletal injured athletes and non-injured athletes) were almost identical for age (24.50 $\pm$ 4.93 and 21.00 $\pm$ 2.80 years), BMI (22.75 $\pm$ 1.24 and 22.88 $\pm$ 0.89 kg/m^2), height (178.50 $\pm$ 5.08 and 181.00 $\pm$ 8.40 cm), and body weight (70.50 $\pm$ 6.56 and 72.00 $\pm$ 5.98 kg). The notable exception was the resting heart rate (46.00 $\pm$ 4.54 and 48.00 $\pm$ 4.24 bpm (p-value = 0.037). After the 2 rounds of testing, all LTs were recorded andthe median differences of the LTs after - before therapy were studied. It was found that the median differences of the LTs in the marker workload and equivalent heart rate between the 2 groups were p-value = 0.528 (-9.75 $\pm$ 60.57 and -29.50 $\pm$ 46.30 watts) and p-value = 0.294 (4.51 $\pm$ 21.84 and -16.09 $\pm$ 26.65 bpm) of the injured group and non-injured group, respectively. The median baseline characteristics and median difference both in the LT parameters for 2 times testing of the lactate between the injured athletes and non-injured athletes were compared with the Mann-Whitney U test (Table 3). In addition, the results of the marker workload (watts) and the equivalent HR in bpm at the fixed anaerobic threshold of 4 mmol•l^{-1} lactate of the injured athletes and non-injured athletes at the first test (before therapy) compared with the second test (after therapy) or at pre- and post-trainings found that therewere 6 positive rankings of the Thai national rowing team athletes, defined as 4 injured athletes and 2 non-injured athletes. They displayed improvement in their cardio-respiration systems which could endure lactic acid in their body for significantly longer periods. The medical records noted 4 knee injuries and 2 cases of myofascial pain syndrome at the upper back, for which injuries it was found that only 1 athlete in each category had the LT improved, and 2 hamstring strains all of whom had an improved LT (Table 4). Low hamstring strength would mean that the forces necessary to resist knee extension and start hip extension during maximal rowing could surpass the tolerance of the muscle-tendon unit. The relationship between the ability of the quadriceps and the capacity of the hamstrings to resist the resulting forces is believed to be critical. Several studies show that athletes with side-to-side strength imbalances may be at an increased risk of injury. The consistent finding that a history of previous injury leads to a several-fold increase in the risk for new strains has, of course, led to the suggestion that this is at least partly due to inadequate rehabilitation and an early return to sport (Bahr, 2013). So, injured athletes must have a discipline of rehabilitation for full recovery before the second test. The results show that they had an improved LT more than the non-injured athletes. The outcome of this experiment encouraged their spirits to overcome their injuries. The method of therapy for the injured athletes found that 3 who had physiotherapy with ultrasound (50%), 1 who had acupuncture (100%), and none in the case with massage, had an improved LT. So the method of therapy was not the factor to impact with performance improvements, even if obsolete therapy. But if the mean of the LT in the marker workload and equivalent HR are considered, it was found that the first test yielded 240.48 ± 50.34 watts and 180.44 ± 16.20 bpm while the second gave 224.28 ± 43.58 watts and 177.50 ± 18.27 bpm, respectively. Again, when comparing the mean differences of the LT in the marker workload and equivalent HR, it was found that 6 athletes had a noticeable improvement but it was not statistically significant (p-value = 0.245 and 0.641, respectively, 95% CI = -12.31 - 44.70 and -10.19 - 16.05, respectively) in the paired samples test.

These experimental studies showing the mean different LTs, implied that the blood lactate concentration during exercise on the rowing machine ergometer was found not only to correspond to the maximal lactate steady state workload but individual anaerobic thresholds should be considered as well. According to a study to ascertain the validity of the anaerobic threshold, it also found a 4.0 $mmol \cdot l^{-1}$ threshold and individual anaerobic threshold as related to a workload corresponding to the maximal lactate steady state. Nine rowers were found to be independent of blood lactate concentration (Beneke, 1995). These rowers regularly undertook rowing training within 24 h prior to ST. However, the effect of this practice has not been investigated. Eight highly trained male club rowers were tested in ST; the participants performed a high-intensity ST session consisting of various multi-joint barbell exercises. The 2,000 m test was repeated at 24 and 48 h post-ST. The study found that performance and related measurements of HR and blood lactate were not significantly affected by ST and this result was identical to this specific study. An important finding was that a bout of high-intensity strength ST

Table 3. Comparison median of baseline characteristics and median difference of lactate threshold parameters with 2 times testing of lactate of the Thai national rowing team athletes with injured athletes and non-injured athletes

Baseline characteristics	Injured athletes N = 8	Non-injured athletes N = 8	*P* value*
Age, year	24.50 ± 4.93	21.00 ± 2.80	0.170
BMI, kg/m^2	22.75 ± 1.24	22.88 ± 0.89	0.873
Height, cm	178.50 ± 5.08	181.00 ± 8.40	0.194
Body weight, kg	70.50 ± 6.56	72.00 ± 5.98	0.747
Resting HR, bpm	46.00 ± 7.29	48.00 ± 4.24	0.037*
Parameter of lactate threshold			
Marker workload, watts	-9.75 ± 60.57	-29.50 ± 46.30	0.528
Equivalent heart rate, bpm	4.51 ± 21.84	-16.09 ± 26.65	0.294

Note : ($p < 0.05$)*

resulted in symptoms of muscle damage and decrements in rowing-specific maximal power, but this did not affect the 2000 m rowing ergometer performance in highly trained rowers (Gee *et al*., 2011).

No athletes in either group received injuries directly from this experiment. As the coach was quite aware of the performance of his athletes, he was the one who set the default power of the marker workload (watts) on the rowing machine ergometer. In the first test, the default power of the marker workload of each athlete was dependent on the individual's physical fitness condition. To train his athletes, he increased the individual default power in the second test. These were considered as confounding factors.

Section III

One hundred and nine Thai national boating team athletes participated at the SUT camp for 6 months, with 90 athletes returning the questionnaires. These 90 respondents consisted of 3 types of boating athletes: 1) 23 rowing athletes: 15 men, 8 women; 2) 50 traditional boat athletes: 25 men, 25 women; 3)17 kayak-canoeing athletes: 10 men, 7 women. Fifty (55.56%) male athletes and 40 (44.44%) female athletes responded to the questionnaires. More than half of these,

Table 4. The results of the marker workload (watts) and the equivalent heart rate in beats per minute (bpm) with the fixed anaerobic threshold of 4 mmol·l^{-1} lactate at pre- and post-training of the injured athletes and non-injured athletes With a description of the symptoms and the method of therapy for the injured athletes

Code	Fixed anaerobic threshold of 4 mmol·l^{-1} lactate				The symptoms of the injured athletes	The method of therapy
	First test		Second test			
	Marker workload	Equivalent heart rate	Marker workload	Equivalent heart rate		
A	271.20	199.37	202.95	175.78	Rt. MCL injury	PT +US
a	320.75	198.22	254.00	178.55	non-injured athletes	none
B	321.80	199.44	273.00	195.36	Rt. LCL injury	PT +US
b	258.00	187.33	228.50	165.20	non-injured athletes	none
C^{+}	201.40	166.76	236.60	168.36	Hamstring strain	PT +US
c	219.40	191.83	162.75	144.03	non-injured athletes	none
D^{+}	217.10	172.26	226.00	179.67	MPS at Rt. rhomboid	PT +US
d	254.50	181.54	225.00	180.47	non-injured athletes	none
E	249.00	180.70	220.60	153.88	MPS at Rt. rhomboid	Massage
e	324.80	190.90	225.00	162.97	non-injured athletes	none
F^{+}	169.50	153.26	180.00	171.91	Hamstring strain	PT +US
f	237.20	183.01	235.60	170.50	non-injured athletes	none
G	201.00	191.46	142.50	218.64	Rt. PFS	PT +US
g^{+}	166.25	143.57	187.00	182.22	non-injured athletes	none
H^{+}	199.50	169.07	314.10	201.25	Rt. Knee tendinitis	Acupuncture
h^{+}	236.30	178.33	275.00	191.34	non-injured athletes	none

Note: + the athletes with improvement, Capital letters = injured athletes, small letters = non- injured athletes, MPS = Myofascial Pain Syndrome, PFS = Patellofemoral pain syndrome, and PT + US = Physical therapy with ultrasound. All injured athletes must do cross training exercise including stretching and strengthening of muscles as well as their method of therapy.

55, (61.11%) were studying, 22 (24.44%) were workers in government military service, especially the navy, and 13 (14.44%) were workers in state enterprises, freelance, and unemployed. Among them 72.22% trained with the RCAT, the maximum number of attendances at the training camp was 10, and the newcomers were reported at 27.78%. Most of these athletes warmed up with stretching for 16.65 ± 7.60 min on average with the maximum being 45 min and the minimum being 5 min. After training, 53 (58.89%) had no more injuries and 37 (41.11%) received more injuries during the SUT camp. When considering the musculoskeletal injuries in specific anatomical areas, 40.48% were at the shoulder, 23.81% at the back, 21.43% at the lower extremities, 11.90% at the upper extremities, and 2.38% at the abdominal wall, respectively. The athletes chose various methods for rehabilitation, although there could be more than 1 method for therapy for each athlete; for instance, 28.05% used physical therapy, 15.85% stretching and strengthening of muscles, 14.63% acupuncture, 12.20% cross training exercise, 10.98% analgesic drugs, 9.76% Thai massage, 4.88% other forms, and 3.66% used no therapy (Table 5). An athlete's reason for not doing rehabilitation might be that the injuries were not severe and could be remitted. Some therapy is not obsolete but is alternative medicine. Dissatisfied with the dominant paradigm of medicine, some physicians have developed an approach to practice based on traditional principles of Western medicine: a respect for the *vis medicatrix nature*, a diagnosis of the individual patient as well as the disease, attention to the whole context of illness, and the formulation of a regimen for each principle does not mean rejecting the conventional approach to diagnosis and treatment whenever this is appropriate. Some of the alternative therapies described above may be included in holistic practice. It is likely that we will see an increasing interchange between mainstream and alternative medicine, with serious attempts to validate alternative practices empirically. There is already at least 1 scientific journal devoted to the subject, The Journal of Alternative and Complementary Medicine (McWhinney, 1997). Methods were selected by the physician for proper injury evaluation and depended on the athlete's selection, it's finding common ground which a part of patient center method (Brown *et al.*, 2003).

The physician communicated with an applied holistic care approach to 37 athletes who had musculoskeletal injuries. Other injuries may have been the result of strenuous training programs or faulty rowing techniques including low back injuries and patellar maltracking (McNally *et al.*, 2005). Thus, cross training exercises must be accompanied with other possible rehabilitation to prevent additional injuries. For the athletes, 56.76% of them were provided with suggestions from the physician who worked in sports medicine and had regular rehabilitation; 63.16% were traditional boat athletes, 55.56% kayak-canoeing athletes, and 44.44% rowing athletes. It was found that 81.08% of the athletes felt their physical fitness relating to musculoskeletal injuries had been improved after rehabilitation. The remaining 16.21% of the athletes were not worse but 2.70% were not better (Table 5). The first 5 opinions on the sport science applications during the SUT camp with a testing scale score range for levels 1, 2, 3, 4, and 5 were as follows; 1) satisfaction with health care system; 4.54 ± 1.04, 2) sport science applications to next camp; 3.93 ± 0.90, 3) getting more knowledge; 3.68 ± 0.67, 4) building more strength; 3.64 ± 0.78, and 5) perceiving more systematical training; 3.63 ± 0.69, respectively. And 87.77% of the 90 athletes who volunteered to answer the questionnaire thought that the sport science applications during the SUT camp had an impact on their practice in total mean = 3.36 ± 0.85. In terms of the benefit of sport science applications towards the whole team, sport science was applied to the whole team but, if considered for each boat category, it was found that the athletes of each boat type had different opinions by one-way ANOVA analysis. The opinions about perceiving more systematic training, building more strength, and creating more motivation were statistically significant and considered $P < 0.05$ (p-value = 0.031, 0.014, and 0.035, respectively, F = 3.61, 4.47, and 3.47, respectively). However, the opinion on getting specialized care was F = 7.84, P = 0.001, and considered $P < 0.01$. The opinions s for decreasing the injury, getting more knowledge, sport science applications at

Table 5. The results of the athletes' backgrounds and method of the athletes' therapy with health care system focused on 37 athletes who had more injuries after training at the SUT camp compiled from the questionnaires of the athletes who responded

Background of athletes	Boat type							
	Rowing		Traditional boat		Kayak-canoeing		All	
	number		number		number		number	
	(persons)	(%)	(persons)	(%)	(persons)	(%)	(persons)	(%)
• Sex								
- male	15	30.00	25	50.00	10	20.00	50	55.56
- female	8	20.00	25	62.50	7	17.50	40	44.44
• Occupation								
- studying	15	65.22	27	54.00	13	76.47	55	61.11
- soldier	5	21.74	16	32.00	1	5.88	22	24.44
- freelance	3	13.04	7	14.00	3	17.65	13	14.44
• Athletes trained with RCAT?								
- no	6	26.09	10	20.00	9	52.94	25	27.78
- yes	17	73.91	40	80.00	8	47.06	65	72.22
• Athletes had more injuries after training during SUT camp?								
- no	14	60.87	31	62.00	8	47.06	53	58.89
- yes	9	39.13	19	38.00	9	52.94	37	41.11
• Methods for rehabilitation (some athletes had more than 1 method of therapy)								
- physical therapy	5	23.81	10	32.26	8	26.67	23	28.05
- muscle stretching	5	23.81	3	9.68	5	16.67	13	15.85
- acupuncture	3	14.29	4	12.90	5	16.67	12	14.63
- cross training	3	14.29	2	6.45	5	16.67	10	12.20
- analgesic drugs	2	9.52	5	16.13	2	6.67	9	10.98
- Thai massage	2	9.52	3	9.68	3	10.00	8	9.76
- other	0	0.00	3	9.68	1	3.33	4	4.88
- no therapy	1	4.76	1	3.23	1	3.33	3	3.66
• Athletes provided with the suggestions from physician								
- irregularly	5	55.56	7	36.84	4	44.44	16	43.24
- regularly	4	44.44	12	63.16	5	55.56	21	56.76
• Athletes opinion of whether their physical fitness after musculoskeletal injuries had been improved after rehabilitation								
- better	7	77.88	15	78.95	8	88.89	30	81.08
- stable	2	22.22	3	15.79	1	11.11	6	16.22
- not improved	0	0.00	1	5.26	0	0.00	1	2.70

the next camp, clinical improvement after rehabilitation, satisfaction of health care system, and impact on practices were not statistically significant (p-value = 0.353, 0.059, 0.144, 0.773, 0.744, and 0.332 respectively, F = 1.05, 2.92, 1.98, 0.26, 0.30, and 1.12, respectively, as shown in Table 6).

When sport science was applied to each boat type during the SUT camp, and each topic was then compared with each boat type by Scheffe analysis, it was found that the opinions about building more strength, creating more motivation, perceiving more systematic training, and getting specialized care were statistically significantly different for each boat type. Kayak-canoeing athletes thought that they gained less strength building and motivation than the rowing athletes, with a mean difference = 0.721 and 0.547 (p-value = 0.14 and 0.05, respectively, 95% CI = 0.12 – 1.32 and 0.00-1.09, respectively). Traditional boat and kayak-canoeing athletes thought that they gained less specialized care and systematic training than rowing athletes, with a mean difference = 0.837, 0.647, and 0.417, 0.486 (p-value = 0.001, 0.047 and 0.043, 0.034 respectively, 95% CI = 0.31 – 1.37, 0.01 - 1.29 and 0.10 – 0.82, 0.03 - 0.94, respectively). The rowing test was a standard for world competition and it required rowing for a long distance, 2000 m, requiring intensive power from well- trained athletes. As a result, their coach was enthusiastic about training his athletes. With only a few members in the team, the coach could pay more individual attention to each of his athletes, and so he could discipline his crews to gain more strength building and have more motivation. Moreover, the coach was trying to provide food supplements for his athletes. It is not surprising that the rowing athletes thought that they were receiving specialized care and systematic training. In contrast, the traditional boat athletes engaged in a variety of long distances (500, 1000, and 2000 m); as a team consisting of 50 members, it could hardly receive such individual attention and systematic training. In addition, the kayak-canoeing team, with distances of 200, 500, and 1000 m, consisted of a lot of teenagers who have been studying and they need motivation to push them to practice and do systematic training. Moreover, muscular men were aiming to gain more strength building and needed specialized care too. Disproportion occurred with the nine members of the sports

Table 6. Comparisons of the opinions of the athletes of the 3 boat types towards the benefit of sport science applications during the SUT camp

Opinions of sport science applications during SUT camp	Mean ± SD from 5 full scores	*F*	*P* value
- Satisfaction of health care system	4.54 ± 1.04	0.30	0.744
- Sport science applications to next camp	3.93 ± 0.90	1.98	0.144
- Getting more knowledge	3.68 ± 0.67	2.92	0.059
- Building more strength	3.64 ± 0.78	4.47	0.014*
- Perceiving more systematic training	3.63 ± 0.69	3.61	0.031*
- Creating more motivation	3.46 ± +0.74	3.47	0.035*
- Getting specialized care	3.42 ± 0.90	7.84	0.001**
- Impact on practices	3.36 ± 0.85	1.12	0.332
- Decrease of injury	3.34 ± 0.85	1.05	0.353
- Clinical improvement after rehabilitation	3.08 ± 0.76	0.26	0.773

*Note: (*p < 0.05, **p < 0.01)*

medicine team which consisted of 1 family physician, 2 nurses, 2 physical therapists, 1 Thai masseur, 1 emergency technician, 1 rehabilitation physician, and 1 acupuncture physician who worked with the researcher for consultation. However, a strategy to augment self-care education was employed by selecting some athletes who volunteered to take care of their team. The doctor is only a small cog in very large wheel where the players and the coaches are the key people. The doctor iss there to provide a service (Brukner, 2013).

Some researchers have found that the success rates of talent identification and development programs had rarely been assessed and that the validity of the models applied remained highly debated. The relevance of this model is highlighted and recommendations for future work provided (Vaeyens *et al.*, 2008). This research shows that the model should continue in a similar manner. Moreover, the application of science to sport was done in physiological profiles of male and female athletes which revealed that what once appeared to be dramatic biological differences in physiological function between the sexes may, in fact, be more related to cultural and social restrictions placed on the female as she attains puberty, i.e. a sedentary lifestyle (Wilmore, 1979). Obviously, it can be seen that sport science has been applied for sport performance for quite some periods of time. To highlight the benefits and the need for sport science support for athletes with learning difficulties, pre- and post-physiological tests along with evaluations of athletes' potential to benefit from sport psychology support were conducted. It is clear that athletes with learning difficulties require the same type of sports science support as their mainstream peers. However, sport scientists will need to consider ways to extend their practice in order to provide the appropriate level of support (Hills and Utley, 2010). Therefore, the benefit of sport science applications during the SUT camp were studied for improvement in the next camp in order to correct all pitfalls for equity and equality in all boat types.

Conclusions

For a doctor, spending a lot of time at team training is important for doing a good job and enjoying the experience to show that all 3 sections of this study were models of supervision of the 3 boat types of the Thai national boating athletes. It has been seen that primary care physicians are becoming more involved in sports medicine both in the office and on the sidelines of athletic events (Luke and Micheli, 1999). The physician can work as part of a team through cooperation with other specialists for recording the athlete's health information and providing consultation. Establishment of an integrated care program in a sports medicine team is recommended, including health promotion, prevention, treatment, and rehabilitation. Athletes should take more time for stretching before practice or competition in addition to strengthening during practice to prevent musculoskeletal injuries.

Basically, the RCAT could use these results in recruiting Thai national boating team athletes, focusing on more specific and in-depth examination of the musculoskeletal injuries of the athletes who should be further investigated in the future. As the results of the median differences towards the LT were not significantly distinct after the experiment, these processes could be seen to encourage athletes to be more interested in rehabilitation in order to perform on an equal basis with non-injured athletes. Moreover, the recordings of sport injuries played an important role for the treatment and assisted planning for a timely recovery prior to competition. Some athletes who had musculoskeletal injuries could be treated in various therapies and could manage their own cross training exercise to wait for the healing process of their injuries especially, and still preserve their cardiovascular and respiratory system too.

Although, there are so many uncontrolled variables which were our limitation. That were personal preferences for own exercises and the programs that were assigned by coach.

Finally, these processes were elicited from the athletes after the application of sport science for them during the SUT camp. Most of the results indicate that their performance improved and that the athletes did appreciate the benefit of sport science applications during the SUT camp, in spite of the fact that the athletes of the 3 boat types had different opinions concerning some topics related to receiving unequal care. Such opinions affected the training of the RCAT team, although overall satisfaction was expressed with the health care system.

Acknowledgments

The facilitation by the director, L. Matrakool and all medical and nursing staff at Suranaree Medical Center at Suranaree University of Technology is appreciated. Thanks also to The Rowing-Canoeing Association of Thailand for funding and supporting the athlete testing, Emeritus professor. V. Vanapruks, for encouragement, B. Khampirat, for statistical advises, *T*. Senakham, for the lactate threshold analysis. And thank you to all the coaches of the 3 boat types, for their kind time and effort and cooperation, as well as the all Thai national rowing athletes. This paper is dedicated to my father, who very recently passed away. His kind influence in my life will be missed.

References

Achten, J. and Jeukendrup, A.E. (2003). Heart rate monitoring: applications and limitations. Sports Med., 33(7):517-538.

Atkinson, K. and Atkinson, C. (2006). Step test. In: The Indoor Rowing Training Guide. O'Neill, K.A.T. and Atkinson, C. (eds). Concept II Ltd, Nottingham, United Kingdom, p. 63-65.

Bahr, R. (2013). Preventing hamstrings strains: A current view of the literature. Aspetar Sports Medicine Journal, 2(targeted topic 2): 494.

Beneke, R. (1995). Anaerobic threshold, individual anaerobic threshold, and maximal lactate steady state in rowing. Med. Sci. Sport. Exer., 27(6): 863-867.

Brown, J.B., Weston, W.W., and Stewart, M. (2003). The third component: finding common ground. In: Patient-Centered Medicine: Transforming the Clinical Method. 2nd ed. Stewart, M., Brown, J.B., Weston, W.W., McWhinney, I.R., McWkilliam, C.L., and Freeman, T.R., (eds). Radcliffe Medical Press, Abingdon, United Kingdom, p. 83-85.

Brukner, P. (2013). Surviving 30 years on the road as a team physician. Br. J. Sport. Med., 41(10):610.

Buono, A.D, Sernia, C., and Maffulli, N. (2013). Definition of acute muscle injury: What have we learnt? Aspetar Sports Medicine Journal, 2(3):342-350.

Dodd, S.L. and Powers, S.K. (2009). Total Fitness & Wellness. 5th ed. Pearson Benjamin Cummings, San Francisco, CA, USA, 432p.

Faude, O,, Kindermann, W., and Meyer, T. (2009). Lactate Threshold Concepts. Sports Med., 39(6):469-490.

Fu, F.H., Tjoumakaris, F.P., and Buoncristiani, A. (2007). Building a sports medicine team. Clin Sports Med., 26(2):173-179.

Gee, T.I., French, D.N., Howatson, G., Payton, S.J., Berger, N.J., and Thompson, K.G. (2011). Does a bout of strength training affect 2,000 m rowing ergometer performance and rowing-specific maximal power 24 h later? Eur. J. Appl. Physiol., 111(11):2653-2662.

Hill, J.C. (2010). Aerobic training. In: Netter's Sports Medicine. Madden, C.C., Putukian, M., Young, C.C., and McCarty, E.C. (ed). Saunders Elsevier, Philadelphia, PA, USA, p. 113-136.

Hills, L. and Utley, A. (2010). Reflections on providing sport science support for athletes with learning difficulties. Disabil. Rehabil., 32(18):1488-1494.

Hosea, T.M. and Hannafin, J.A. (2012). Rowing injuries. Sports Health, 4(3):236-245.

Junge, A., Engebretsen, L., Mountjoy, M.L., Alonso, J.M., Renstrom, P.A., Aubry, M.J., and Dvorak, J. (2009). Sports injuries during the Summer Olympic Games 2008. Am. J. Sport. Med., 37(11):2165-2172.

Karlson, K.A. (2000). Rowing injuries: identifying and treating musculo-skeletal and nonmusculoskeletal conditions. Physician Sportsmed., 28(4):40-50.

Luke, A. and Micheli, L. (1999). Sport injuries: Emergency assessment and fField-side care. Pediatr. Rev., 20(9):291-300.

Madden, C.C., Putukian, M., Young, C.C., McCarty, E.C., Mellion, M. B., and Walsh, W. M. (2010). The team physician. In: Netter's Sports Medicine. Madden, C.C., Putukian, M., Young, C.C., and McCarty, E.C. (eds). Saund,ers Elsevier, Philadelphia, PA, USA, p. 3-7.

McNally E., Wilson, D., and Seiler, S. (2005). Rowing injuries. Semin. Musculoskel. R., 9(4):379-396.

McWhinney, I.R. (1997). A Textbook of Family Medicine. 2nd ed. Oxford University Press, New York, NY, USA, 448p.

Newell, J., Higgins, D., Madden, N., Cruikshank, J., and Einbeck, J. (2005). Software for calculating blood lactate endurance markers. J. Sport. Sci., 25(12):1,403-1,409.

Peterson,, M.D., Rhea, M.R., and Alvar, B.A. (2004). Maximizing strength development in athletes: a meta-analysis to determine the dose response relationship. J. Strength Cond. Res., 18(2):5, 377.

Ratamess N. (2012). ACSM's Foundations of Strength Training and Conditioning. Lippincott Williams & Wilkins, Philadelphia, PA, USA, 500p.

Rumball, J.S. and Lebrun, C.M. (2010). Rowing. In: Netter's Sports Medicine. Madden, C.C., Putukian, M., Young, C.C., and McCarty, E.C. (eds). Saunders Elsevier, Philadelphia, PA, USA, p. 679-685.

Rumball, J.S., Lebrun, C.M., Di Ciacca, S.R., and Orlando, K. (2005). Rowing injuries. Sports Med., 35(6):537-555.

Seeley, R., Stephens, T., and Tate, P. (2011). Anatomy and Physiology. McGraw-Hill, New York, NY, USA, 1,116p.Stegmann, H., and Kindermann, W. (1982). Comparison of prolonged exercise tests at the individual anaerobic threshold and the fixed anaerobic threshold of 4 mmol?l-1 lactate. Int. J. Sports Med., 3(2):105-110.

Vaeyens, R., Lenoir, M., and Williams, A.M., and Philippaerts, R.M. (2008). Talent identification and development programmes in sport: current models and future directions. Sports Med., 38(9):703-714.

Wilmore, J.H. (1979). The application of science to sport: physiological profiles of male and female athletes. Can. J. Appl. Sport Sci., 4(2):103-115.