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ORIGINAL

REDUCTION OF FAT-FREE MASS IN SWIMMERS AFTER TRAINING PERIOD

REDUCCIÓN DE MASA LIBRE DE GRASA EN NADADORES DESPUÉS DE UN PERIODO DE ENTRENAMIENTO

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ABSTRACT

An increase in fat-free mass (FFM) improves athletic performance. The aim of this study was to determine if a decrease in the FFM, expressed as the AKS index, is associated with physiological alterations after a training period in swimmers between 8-15 years old. Forty-two swimmers participated in this study, after 15 weeks of training the swimmers were divided into two groups, those who decreased (A) and those who increased FFM (B). In group A there was a decrease in both, body weight and muscle, mass while in group B there was an increase in body weight. We found that group A showed a reduction in lymphocytes count, in addition to an increase in serum urea, a decrease in VO_2, and a decrease in their 1 min recovery. We showed here that a reduction in FFM is positively associated with physiological alterations that reduce athletic performance.

KEY WORDS: Adolescents, schoolchildren, active body substance index (AKS), swimming.

RESUMEN

En los deportistas la masa libre de grasa (MLG) es una característica física que se busca incrementar para aumentar el rendimiento deportivo. El objetivo de este estudio fue determinar si la reducción de la MLG, expresada como índice AKS, se asocia a alteraciones fisiológicas después de un periodo de entrenamiento en nadadores de 8 a 15 años de edad. Se estudiaron 42 nadadores, después de 15 semanas de entrenamiento se formaron 2 grupos, los que disminuyeron (A) y aumentaron (B) MLG. Se encontró que el grupo A redujo el peso y la masa muscular mientras que en el grupo B aumentó. En el grupo A se observó una disminución en los linfocitos, un aumento en la urea sérica, una disminución en el VO_2 y en la recuperación a un minuto. La reducción de la MLG se asoció con alteraciones fisiológicas que reducen el rendimiento deportivo.

PALABRAS CLAVE: Adolescentes, escolares, índice de sustancia corporal activa (AKS), natación.

INTRODUCTION

In Mexico, overweight and obesity (Ow&Ob) are a public health problem, it is estimated that at a national level the prevalence of Ow&Ob in schoolchildren and adolescents is 33.2% and 36.3%, respectively (Hernández-Ávila *et al.*, 2016). One of the main strategies for Ow&Ob prevention and control in schoolchildren and adolescents is the promotion of physical activity (Barquera *et al.*, 2010; Vera-Estrada *et al.*, 2018). One way to promote physical activity is through sports, in this regard it has been shown that sport in schoolchildren and adolescents have multiple physiological and psychological benefits (Merkel, 2013). The positive physiological adaptations that sport generates occur if there is a gradual increase in training loads, with the appropriate intensity, duration, and frequency (Pancorbo, 2003). One of the main physiological adaptations that occur through sports is the reduction of low density lipoproteins (LDL) and the increase in high density lipoproteins (HDL); thus reducing cardiovascular risk in schoolchildren and adolescents (Koozehchian *et al.*, 2014). Sport also decrease resting heart rate and fat mass; in addition, increase bone resistance, muscle mass, free fat mass (FFM), the oxygen uptake (VO_2), the glycogen reserve, among other positive effects (Merkel, 2013; Nalcakan, 2014; Stasinaki *et al.*, 2015). However, in case of greater requirement in training, the adaptation mechanisms of the athlete may fail due to the stress generated (Pancorbo, 2003; Brandão *et al.*, 2015). This condition generally occurs when there is an intense training for a long period of time, before competition events, in addition to little recovery time between them (Veal, 1991; Meeusen *et al.*, 2006; Kreher and Schwartz, 2012). As a consequence, the athlete may experience fatigue, lower performance and mood changes (Brandão *et al.*, 2015; Veal, 1991; Griffin *et al.*, 1999). This is partially due to an increase in protein catabolism which promotes a decrease in muscle mass (Johnson and Thiese, 1992). The importance of muscle mass gain during sports activity is associated to increase in strength, endurance, bone mineral density, VO_2 and a decrease in musculoskeletal injuries (Hart *et al.*, 1985; Schiplilow *et al.*, 2013).

In order to assess the gain of FFM in schoolchildren and adolescents, the active body substance (AKS) index can be used; this value determines the amount of FFM in relation to the height of the subjects (Tittel and Wutscherk, 1972; Henríquez-Pérez *et al.*, 2009). The AKS index was originally described and applied to the evaluation of muscle development in athletes, and it is useful in the nutritional anthropometric evaluation of schoolchildren and in growing and developing athletes. It is also known that the AKS index is useful for estimating the level of musculoskeletal development (Henríquez-Pérez *et al.*, 2009; Serrato-Roa, 2008).

The aim of this study was to determine the association of loss of FFM, estimated through the AKS index, with physiological alterations in schoolchildren and adolescent swimmers after a period of 15 weeks of training.

MATERIAL AND METHODS

Design and study population

An observational, prospective and comparative study was conducted. An amateur swimming team was invited to participate in Querétaro (central Mexico). The team consisted of 64 schoolchildren and adolescents from 8 to 15 years old. The swimmers' training consisted of 2h in the pool and 1h on the track per day, for a total of 5 days/week, for 15 weeks. All participating swimmers dominated the four swimming strokes (freestyle, backstroke, breaststroke and butterfly stroke), and they had at least one year of continuous training.

The training objectives were to increase the physical abilities of swimmers such as endurance, strength, speed, flexibility, coordination, balance and agility. During this study, at no time there was an interference with the training as scheduled by the team's coaches. The study began after a transition stage before a holiday period (January) and concluded until after a competition stage (April). After 15 weeks of training, two groups were formed according to the modification in the FFM expressed as the AKS index. Schoolchildren and adolescents who decreased the AKS index were in group A, and those who increased it were in group B. Swimmers who had an injury during the study period and those who missed training for more than 3 times during the 15 weeks period were excluded. In addition, those participants in whom not all analyzes were performed were removed from the study. All swimmers participated freely and voluntarily under the informed consent (free and clear) signed by at least one of the parents or legal guardians. This study was approved by the Bioethics Committee of the Facultad de Medicina de la Universidad Autónoma de Querétaro (Registration number 01-07/08/2014) observing the principles of the Declaration of Helsinki.

Anthropometric measurements

Weight, height, waist (WCi) and hip (HCi) circumferences were measured according to standard procedures (World Health Organization, 1995). The weight of all participants was recorded in fasting conditions using an electronic scale (JAWON Medical X-Scan Plus II; Korea). Height was determined using a stadiometer (SECA 206, Germany). Nutritional status including growth rates, z-scores for weight-for-age, height-for-age and body mass index (BMI)-for-age were determined using the criteria of the World Health Organization (OMS, 2008), considering overweight school children and adolescents with a z-score between 1 and 1.99 of BMI for age, and as obese with a z-score ≥ 2.

Body composition analysis

Body composition was performed by mean of tetrapolar electrical bioimpedance using 8 tactile electrodes (JAWON Medical X-Scan Plus II; Korea), recording the data for percentage of fat, FFM, soft tissue, muscle mass, bone mass, total body water, intracellular water and the AKS index was calculated with the following formula (Henríquez-Pérez *et al.*, 2009): FFM in kg/height m3 x 10.

Biochemical analyses

All participants had a fasting blood sample obtained by peripheral venous puncture. Glucose, urea, creatinine levels and lipid profiles were determined (A15

Biosystems, Spain) and a complete blood count was performed (Kx-21N Sysmex, USA). For all laboratory procedures the indications of manufacturer were followed.

Metabolic analyses

The VO_2, carbon dioxide production (VCO_2), respiratory quotient, resting metabolic rate (RMR) and resting heart rate were determined by indirect resting calorimetry with a Cardio-Coach CO_2 equipment (KorrTM Medical Technologies Inc., USA). Participants over 12 years of age underwent an indirect postprandial calorimetry in movement in a treadmill (Prisma, M10 66110, BH Fitness, Germany) under the modified Bruce protocol (Marshall *et al.*, 2014), keeping the slope constant at 10º. The calorimetry in movement consisted in that every 3 min the speed increased 2 km/h starting at 4 km/h. Indirect calorimetry was performed 2h after the subjects received a standardized breakfast, and 24h after their last exercise. In the calorimetry in movement, VO_2, VCO_2, respiratory quotient, energy expenditure and metabolic equivalents (METS) were also determined. METS are defined as the oxygen consumed at rest to express the energy expenditure of physical activity as a multiple of the resting metabolic rate, the aerobic threshold, the anaerobic threshold and the maximum peak of VO_2. The initial heart rate during recovery was also determined, at one minute and two minutes later. To rule out heart problems before performing the calorimetry in movement, a 12-channel surface electrocardiogram (Smart Wav 15 SonoMedic) was performed by an experienced pediatric cardiologist. The unipolar and bipolar electrodes were placed in the ventral position using the standard pediatric technique. Registration was performed without having drinks with caffeine or food ingestion for the last 2h.

Statistical analyses

The initial and final data were analyzed with the Student's t-test for the parametric variables and the Mann Whitney U-test for the non-parametric variables; a statistical significance of $p < 0.05$ was accepted. The GraphPad Prism 5® statistical and graphics program (Graph Pad Inc., USA) was used.

RESULTS

From the 64 members of the swimming team only 42 subjects were included in this study and the remaining 22 subjects were excluded either because did not meet the inclusion criteria or decided not to participate. From the 42 participants that were included in the study, 24 (57%) were women and 18 men, 20 (48%) schoolchildren and 22 (52%) adolescents. The average age was 11.8 years in the initial evaluation. When comparing the initial measurement *versus* the final one, an increase in size was observed due to the effect of age; however, the z-score for height-for-age value decreased (-8.9%; Table 1).

Based on BMI-for-age, the percentage of swimmers with Ow&Ob at the beginning of the study was 26%, 10 overweight and 1 obese (data not shown). At the end of the study, the percentage of overweight swimmers was 24% and none was found obese (data not shown). The participant with obesity at baseline reduced his BMI-for-age, however, he did not change his fat mass (initial: 14.4 kg *versus* final: 14.4 kg); the lost body weight in this participant was at the expense of muscle mass (initial: 13.8 kg *versus* final: 13.4 kg) for that reason also the AKS index was also reduced (initial: 1.21 kg/m^3 *versus* final: 1.19 kg/m^3; data not shown). On the other hand, there were no participants with malnutrition.

The main changes that occurred in the study group (Table 1), like a decrease in resting heart rate and an increase in HDL, LDL, total cholesterol and triglycerides levels. HDL levels on average were higher than the normal range (>60 mg/dl). 2.3% of swimmers had high LDL (>160 mg/dl), 9.5% showed high triglycerides (> 150 mg/dl) and 6.6% showed elevated total cholesterol (>200 mg/dl). In 14%, elevated levels of hemoglobin, hematocrit and mean corpuscular volume were present. Likewise, it was observed that creatinine increased while maintaining normal values, and there was an increase in the respiratory quotient.

Table 1. Anthropometric, body composition and biochemical characteristics of schoolchildren and adolescents swimmers after 15 weeks of intense exercise.

Variable	Initial measurement (n=42)	Final measurement (n=42)	*p*
Age (years)	11,8 ± 1,8	12,1 ± 1,8	< 0,0001
Weight (kg)	43,4 ± 9,7	43,6 ± 9,1	< 0,01
Height (cm)	152,1 ± 11,5	153,2 ± 11,1	< 0,0001
Height for age (z-score)	0,43 ± 0,75	0,28 ± 1,04	< 0,01
BMI of age (z-score)	0,24 ± 1,00	0,16 ± 0,96	< 0,01
AKS index (kg/m^3)	1,012 ± 0,10	1,017 ± 0,10	NS
Fat body mass (%)	16,9 ± 7,1	17,1 ± 6,4	NS
Muscle mass (kg)	13,7 ± 3,4	13,9 ± 3,6	NS
Glucose (mg/dl)	82,2 ± 6,8	85,7 ± 7,4	< 0,01
HDL-C (mg/dl)	42,6 ± 6,7	49,8 ± 11,9	< 0,0001
LDL-C (mg/dl)	88,4 ± 30,1	104,4 ± 26,2	< 0,0001
Triglycerides (mg/dl)	63,1 ± 30,7	90,1 ± 55,2	< 0,01
Total cholesterol (mg/dl)	163,9 ± 31,6	172,3 ± 28,4	< 0,01
Urea (mg/dl)	33,7 ± 9,3	32,8 ± 7,5	NS
Creatinine (mg/dl)	0,7 ± 0,1	0,6 ± 0,1	< 0,01
Respiratory quotient	0,8 ± 0,1	0,9 ± 0,1	< 0,05
VO_2 (ml/kg/min)	5,3 ± 2,2	5,1 ± 1,3	NS
Heart rate (bpm)	80,7 ± 16,6	74,9 ± 10,5	< 0,01

AKS: Active body substance; BMI: Body mass index; bpm: beats per minute; HDL: high density lipoproteins; LDL: low density lipoproteins; VO_2= oxygen uptake; NS= No significant. Values represent the median ± standard deviation.

It was found that 52.3% (n= 22) of the participants reduced their AKS index, after 15 weeks of training, while 33% (n= 14) increased it, discarding 4.7% (n= 6) that showed no changes in this parameter (Table 2). Group A reduced weight (-0.1%), WCi (-1.5%), HCi (-2.4%) and the waist/height index (-2,3%). On the contrary, group B increased weight (1.9%), height (0.8%), WCi (1.9%) and HCi (2.1%). In relation to the body composition it was observed that group A also reduced FFM (-0.2%), soft tissue (-0.2%), muscle mass (-3.3%), bone mass (-0.2%), total body water (-0.2%) and extracellular water (-1.6%). On the contrary, an increase in FFM (4.6%), soft tissue (4.6%), muscle mass (8.8%), bone mass (3.6%) was observed in group B, as well as total body water (5.2%), intracellular water (4.6%) and extracellular water (4.8%).

Table 2. Comparison of the anthropometric, body composition and final biochemical variables less initial (∆) of both groups after 15 weeks of intense exercise.

Variables	Group A AKS reduction (n=22)	Group B AKS increase (n=14)	*P*
Anthropometry			
Weight (kg)	-0,1 ± 1,2	1,9 ± 1,2	< 0,0001
Waist circumference (cm)	-1,0 ± 2,0	1,9 ± 2,0	0,0001
Hip circumference (cm)	-2,1 ± 4,1	1,6 ± 1,7	0,0001
Waist/stature ratio	-0,01 ± 0,01	0,01 ± 0,01	< 0,0001
AKS index (kg/m^3)	-0,03 ± 0,01	0,03 ± 0,03	< 0,0001
BMI-for-age (z-score)	-0,2 ± 0,2	0,1 ± 0,2	< 0,0001
Body composition			
Free fat mass (kg)	-0,1 ± 0,4	1,6 ± 0,9	< 0,0001
Fat body mass (%)	0,8 ± 3,3	0,0 ± 1,5	NS
Total fat mass (kg)	0,0 ± 0,9	0,3 ± 0,7	NS
Soft tissue (kg)	-0,1 ± 0,3	1,5 ± 0,8	< 0,0001
Muscle mass (kg)	-0,5 ± 0,6	1,2 ± 0,9	< 0,0001
Bone mass (kg)	0 ± 0,1	0,1 ± 0,1	< 0,01
Total body water (kg)	-0,1 ± 0,3	1,3 ± 0,8	< 0,0001
Intracellular water (kg)	0,1 ± 0,3	0,7 ± 0,4	< 0,0001
Extracellular water (kg)	-0,2 ± 0,2	0,5 ± 0,4	< 0,0001
Biochemical parameters			
Urea (mg/dl)	2,6 ± 9,9	-4,4 ± 8,9	< 0,05
Lymphocytes (k/µl)	-1,89 ± 4,48	2,38 ± 5,17	< 0,01
Hemoglobin (mg/dl)	0,1 ± 1,0	-0,4 ± 0,9	< 0,05

AKS: Active body substance; BMI: Body mass index; NS= No significant. Values represent the median ± standard deviation.

Based on the analysis of biochemical markers group A increased serum urea (13.4%) and decreased the number of lymphocytes (-5.8%), within normal reference values. Group B showed a reduction in serum urea (-8.1%) and hemoglobin (-2.6%), while lymphocyte counts increased (12.1%). Regarding the resting metabolic variables, VO_2 increased in both groups (4.5% and 8.9%; respectively for groups A and B; Table 3); on the other hand, in group B the RMR value increased (9.1%). During the Bruce protocol, group B decreased VO_2 in the initial stage (-34.9%), the METS in the initial stage (-35.5%) and the rapid recovery value at one minute (-14.6%) (Table 4).

Table 3. Comparison of metabolic variables at rest at final less initial (Δ) of both groups after 15 weeks of intense exercise.

Variable	Group A AKS decrease (n=17)	Group B AKS increase (n=8)	*p*
Hearth rate (bpm)	-9,5 ± 15,7	-1,6 ± 10,5	NS
VO_2 (ml/min)	-0,05 ± 21,3	17,1 ± 30,9	<0,05
VO_2 (ml/kg/min)	0,0 ± 0,5	0,2 ± 0,6	NS
VCO_2 (ml/min)	4,5 ± 15,2	11,8 ± 27,3	NS
VCO_2 (ml/kg/min)	0,1 ± 0,7	0,2 ± 1,0	NS
RMR (kcal)	-6,8 ± 150,6	120,8 ± 210,6	< 0,05
RMR/FFM (kcal/kg)	-0,2 ± 4,7	1,5 ± 4,7	NS
RMR/Muscle mass (kcal/kg)	2,8 ± 16,3	0,6 ± 11,9	NS
Respiratory quotient (CO_2/O_2)	0,03 ± 0,1	0,01 ± 0,1	NS
Carbohydrates (%)	10,5 ± 33,2	1,2 ± 31,1	NS
Fats (%)	-10,5 ± 33,1	-1,2 ± 31,1	NS

AKS: Active body substance; bpm: beats per minute; RMR: resting metabolic rate. VO_2: oxygen uptake; VCO_2: Carbon dioxide production; FFM: Free fat mass; NS: No significant. Values represent the median ± standard deviation.

Table 4. Comparison of metabolic variables at movement at final less initial (Δ) of both groups after 15 weeks of intense exercise.

Variable	Group A AKS decrease (n=5)	Group B AKS increase (n=4)	*p*
VO_2 initial (ml/min)	0,2 ± 2,2	-6,0 ± 5,4	< 0,05
VO_2 anaerobic threshold (ml/min)	11,4 ± 10,0	2,9 ± 10,7	NS
VO_2 aerobic threshold (ml/min)	12,6 ± 7,9	2,7 ± 16,6	NS
VO_2 peak (ml/min)	4,1 ± 9,4	-2,5 ± 2,8	NS
Initial heart rate (bpm)	-16,8 ± 38,9	-13,5 ± 3,8	NS
Heart rate anaerobic threshold (bpm)	13,4 ± 26,0	-1,0 ± 22,5	NS
Heart rate aerobic threshold (bpm)	9,0 ± 15,9	3,3 ± 33,0	NS
Heart rate peak (bpm)	-4,2 ± 6,4	-9,0 ± 1,8	NS
METS initial	0,0 ± 0,6	-1,7 ± 1,5	<0,05
METS anaerobic threshold	3,3 ± 2,8	0,8 ± 3,1	NS
METS aerobic threshold	3,6 ± 2,2	0,8 ± 4,7	NS
METS peak	1,2 ± 2,7	-0,8 ± 0,8	NS
Recovery peak (bpm)	-4,2 ± 6,4	-9,0 ± 1,8	NS
Recovery 1 min (bpm)	-0,2 ± 10,9	-20,8 ± 13,6	<0,05
Recovery 2 min (bpm)	-7,2 ± 6,6	-28,8 ± 21,3	NS
Aerobic threshold (min)	2,6 ± 2,6	1,2 ± 4,2	NS
Anaerobic threshold (min)	2,5 ± 3,9	0,9 ± 0,6	NS

AKS: Active body substance; bpm: beats per minute; METS: metabolic equivalents; NS: No significant. Values represent the median ± standard deviation.

DISCUSSION

The physical-sports activity provides psychological and physiological benefits for the subjects who practice it habitually (Merkel, 2013). The HF-Action study (O'Connor *et al.*, 2009) reported that subjects who performed physical activity reduced by 11% and 15% the risk of hospitalization for cardiac causes and death from cardiovascular disease; respectively. The data of the present study showed that the swimmers presented physiological cardiovascular adaptations representing an improvement in physical fitness, such as the decrease in resting heart rate; and an increase in hemoglobin, hematocrit and mean corpuscular volume (Boraita *et al.*, 2000; Santhiago *et al.*, 2009). However, the reduction in height-for-age suggests that height gain was compromised in order to meet the energy demand of the physical activity (Maïmoun *et al.*, 2014).

The increase in FFM and especially muscle mass is important for the athletes as they are related to greater physical abilities and prevention of musculoskeletal injuries (Pancorbo, 2003). In group A, the lost body weight was at the expense of FFM and not at the expense of adipose tissue. In order to prevent this loss, a consumption of 1-2.3 g of protein/kg of body weight is recommended for the maintenance of FFM in young athletes during training (Mettler *et al.*, 2010). One of the main limitations of this study was the lack of evaluation of diet consumption. Mello *et al.* (2015), in adolescent swimmers, indicated that this age group should have a very close nutritional surveillance, because they usually have an excessive consumption of food supplements, high energy and protein consumption and a low intake of carbohydrates and micronutrients. In addition, the loss of the swimmers' FFM could be explained by an insufficient diet for their energy and nutritional needs; however, we found overweight but no swimmers with undernutrition. Likewise, it is important to consider the growth and development of the athlete who performs intense physical activity in order to take care of the diet, rest times and training that affect him in his physical development and avoid psychological changes such as frustration in the face of sports failures (Merkel, 2013).

In group A, serum urea probably increased in relation to the increase in exercise intensity and increased protein catabolism, suggesting a negative nitrogen balance (Pancorbo, 2003). On the other hand, in group B the serum urea decreased suggesting protein anabolism, reflected in an increase in muscle mass (Pancorbo, 2003). The decrease in the number of lymphocytes suggests changes in the immune system of the subjects that may be due to different causes, including stress (Gleeson *et al.*, 1995).

In calorimetry at rest, VO_2 increased in group B, possibly because swimming is in greater proportion an aerobic exercise that demands significant oxygen transport. This type of training increases the maximum oxygen consumption and therefore increases the physical condition (Nikolic and Ilic, 1992). In group B the energy requirement increased by approximately 120 kcal, while in group A the RMR decreased, this was probably due to the decrease in FFM (Marchini *et al.*, 2005; Vargas *et al.*, 2011).

Regarding the calorimetry in movement it was observed that group B had a better adaptation to the exercise with a lower energy expenditure at the start of the test measured by the METS, in addition to achieving a better recovery with 20 beats per minute less at one minute of recovery, reflecting an adequate physical condition (Knechtle, 2014; Winsley and Matos, 2011). Interestingly, in group A no modifications were observed. These data suggest that this information could be used for training planning, using frequencies, volumes and thresholds (Ramos-Álvarez *et al.*, 2016).

Finally, another limitation of the work to consider was the lack of analysis of psychological variables such as stress and anxiety. These psychological factors can impact on different levels affecting, food, sleep, motivation to train, among other causes (Stults-Kolehmainen and Sinha, 2015; Pancorbo, 2003). Some probable sources of psychological stress that can affect physical activity and training, but which were not analyzed in this work, are the demands of parents and coaches as well as the athletes' own social commitments such as academic performance in school. In this regard, it is convenient to emphasize the recommendation to parents and coaches to closely monitorize the young athletes training through the care of food, adequate sleep and the appearance of behaviors different from the usual in order to prevent stress.

CONCLUSIONS

Intense exercise accompanied by a decrease in FFM has adverse effects that may have an impact on sports performance and health. Multidisciplinary surveillance of a health team for the athlete is essential to ensure that athletes do not present the risks of an unsupervised sports activity.

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