DOI: 10.4274/anatoljmed.2024.36844
Anatol J Gen Med Res 2024;34(3):249-56

CLINICAL RESEARCH / KLİNİK ARAŞTIRMA

ANATOLIAN JOURNAL of GENERAL MEDICAL RESEARCH

Evaluation of the Responses to the Tilt Table Test of Young Male Adolescents Who Dominantly Isometric and Isotonic Sports

İzometrik ve İzotonik Sporları Ağırlıklı Olarak Yapan Genç Erkek Adölesanların Tilt Table Testine Verdikleri Yanıtların Değerlendirilmesi

Cemaliye Başaran[1], Selda Bereket Yücel[2], Şenol Coşkun[3]

[1]University Health Sciences Turkey, İzmir Tepecik Education and Research Hospital, Clinic of Pediatrics, Division of Nephrology, İzmir, Turkey
[2]Marmara University Faculty of Physical Education and Sports, Department of Kinesiology and Training, İstanbul, Turkey
[3]Manisa Celal Bayar University Faculty of Medicine, Department of Pediatrics, Division of Pediatrics Cardiology, Manisa, Turkey

Cite as: Başaran C, Bereket Yücel S, Coşkun Ş. Evaluation of the Responses to the Tilt Table Test of Young Male Adolescents Who Dominantly Isometric and Isotonic Sports. Anatol J Gen Med Res. 2024;34(3):249-56

Abstract

Objective: The autonomic nervous system is an issue that needs to be examined due to the symptoms that develop due to orthostatic intolerance when a person stands up. Nowadays, it is recommended to do sports regularly from childhood. In addition, there are many different ideas about which muscle groups work and how they work, and which sport is more beneficial. In our study, we aimed to examine the responses of the autonomic nervous systems to position changes in children who do regular and different sports.

Methods: The most commonly used head-up tilt test to detect orthostatic intolerance. Fifteen male wrestlers who dominantly do isometric sports, 15 male basketball players who dominantly do isotonic sports, and 15 children of similar age and gender who do not do regular sports participated in our study. After the children were placed on a tilt table and rested for 15 minutes, the table was turned to 70 degrees and their pulse and blood pressure were measured for 50 minutes, 65 minutes in total.

Results: In our study, basal cardiac pulse values were found to be lower in the athlete groups than in the control group, more clearly in the wrestler group doing isometric sports. There was an increase in cardiac pulses upon standing up in all groups. During the test, systolic blood pressure values were found to be higher in the wrestlers than in the control group, while basal diastolic blood pressure values were found to be significantly lower in the athlete groups.

Conclusion: The fact that there is a greater increase in diastolic blood pressure upon standing up in those who dominantly isometric sports compared to those who dominantly isotonic sports suggests the need to do dominantly isometric movements to prevent orthostatic intolerance which is the most common cause of vasovagal syncope.

Keywords: Exercise, head-up tilt test, orthostatic intolerance

Address for Correspondence/Yazışma Adresi: Cemaliye Başaran MD, University Health Sciences Turkey, İzmir Tepecik Education and Research Hospital, Clinic of Pediatrics, Division of Nephrology, İzmir, Turkey
E-mail: cemaliyebasaran@gmail.com
ORCID ID: orcid.org/0000-0002-6422-7998

Received/Geliş tarihi: 08.10.2023
Accepted/Kabul tarihi: 08.02.2024

***This study was previously presented as an oral presentation at the 3rd. International Behçet Uz Children's Congress, which was held between 23-25 September 2021.**

Öz

Amaç: İnsan ayağa kalktığında ortostatik intoleransa bağlı gelişen semptomlar nedeniyle otonom sinir sistemi irdelenmesi gereken bir konudur. Günümüzde sporun çocukluk çağlarından itibaren düzenli bir şekilde yapılması önerilmektedir. Ayrıca yapılan egzersizlerde hangi kas gruplarının nasıl çalıştığı dolayısı ile hangi sporun daha yararlı olduğuna dair çok çeşitli fikirler bulunmaktadır. Çalışmamızda düzenli ve farklı spor yapan çocukların pozisyon değişikliklerine otonom sinir sistemlerinin verdiği yanıtları incelemeyi amaçladık.

Yöntem: Ortostatik intoleransın saptanmasında en yaygın kullanılan head-up tilt testidir. Çalışmamıza izometrik ağırlıklı spor yapan 15 erkek güreşçi, izotonik ağırlıklı spor yapan 15 erkek basketbolcu ve yaş ve cinsiyet benzer, düzenli spor yapmayan 15 çocuk alınmıştır. Tilt masasına yatırılan çocuklara 15 dakika dinlenmeyi takiben masa 70 derece konuma getirilerek 50 dakika, toplamda 65 dakika boyunca nabız ve kan basıncı ölçümü yapılmıştır.

Bulgular: Çalışmamızda izometrik ağırlıklı spor yapan güreşçi grubunda daha belirgin olmak üzere bazal kardiyak nabız değerleri sporcu gruplarda kontrol grubuna göre düşük saptanmıştır. Tüm gruplarda ayağa kalkma ile beraber kardiyak nabızlarında artma olmuştur. Test boyunca sistolik tansiyon değerleri güreşçilerde kontrol grubuna göre yüksek saptanırken bazal diyastolik tansiyon değerleri sporcu gruplarda anlamlı şekilde düşük saptanmıştır.

Sonuç: İzometrik ağırlıklı spor yapanlarda ayağa kalkma ile beraber diyastolik kan basıncında izotonik ağırlıklı spor yapanlara göre daha fazla artışın olması vasovagal senkopun en sık görülen nedeni olan ortostatik intoleransın önlenmesinde izometrik ağırlıklı hareketlerin daha fazla yapılması gereğini düşündürmektedir.

Anahtar Kelimeler: Egzersiz, head-up tilt testi, ortostatik intolerans

Introduction

Changes in the cardiovascular system due to changes in the position of the human body have been a subject of constant interest and curiosity. Factors that are effective in regulating blood flow during body position changes; gravity, autonomic nervous system, cardiovascular system, central nervous system and endocrine system[1].

The response of the autonomic nervous system varies the most in a healthy person. Therefore, the autonomic nervous system response in people who experience symptoms with changes in body position is a subject that is widely evaluated. Nowadays, it is recommended to perform sports regularly starting from childhood for the cardiovascular system to function healthily. In addition, various ideas have been put forward about which sport is more beneficial due to the type of sport and which muscle groups work in which way in the exercises. The most important problem in position changes is orthostatic intolerance, which develops because of the displacement of blood in the body[2]. Although various methods are used to detect orthostatic intolerance, the head-up tilt test is currently the most used for this purpose[3-6].

Because the contraction patterns of various muscle groups in our body differ during our movements, their effects on the cardiovascular system are also different[7]. Isometric muscle contraction is a type of contraction in which the muscle tone increases while its length remains constant. This is also called static muscle contraction. In isotonic muscle contraction, the muscle length shortens (concentric) or lengthens (eccentric). Also called dynamic muscle contraction. In both types of contractions, the heart rate increases. This increase in heart rate is largely dependent on decreased vagal tone, although increased cardiac sympathetic nerve discharge also plays a role. During isometric muscle contraction, systolic and diastolic blood pressures rise sharply. Stroke volume changes relatively less, and blood flow to the constantly contracting muscles decreases because of their pressure on the blood vessels. Unlike isotonic contraction, there was a significant increase in stroke volume in this table. In addition, there was a clear decrease peripheral resistance due to vasodilation in the exercising muscles. As a result, systolic blood pressure increased moderately, whereas diastolic blood pressure generally remained unchanged or decreased. Mean arterial pressure increases because cardiac output increases because of the decrease in total peripheral pressure[8,9]. The exercises that people perform in their daily lives also include a combination of dynamic and static exercises.

In this study, we aimed to examine the responses of the autonomic nervous system to position changes in children who play sports regularly and with different characteristics and to determine which of the results is the desired response to position changes.

Materials and Methods

The study included 15 male athletes who have been actively working for at least 3 years in the sport of wrestling, where isometric muscle contraction is used more intensely, and in the sport of basketball, where isotonic muscle contraction is used more frequently (training for at least 2 h for 4 days a week and participating in domestic and international competitions). The control group was selected from individuals of similar age and gender who were not actively involved in any sports. Ethical approval for the study was obtained (Manisa Celal Bayar University Faculty of Medicine, 2005/0001).

Tilt Table Test Protocol

All subjects tested had fasted the night before or had eaten at least 2-3 hours before monitoring, if the test was performed early in the morning. After the subjects were informed about follow-up, a written consent form was signed. The subjects were monitored after being connected to the tilt table. All subjects were allowed to rest in the supine position for approximately 15 min before the start of the test to stabilize their heart rate and blood pressure. Then, the tilt table was tilted to 70° and the subjects were allowed to stand for 50 min, which was the test period. Cardiac rhythm, heart rate, and blood pressure were monitored with at least 3-lead ECG recording with a continuous monitor at 3-min intervals. Pharmacological provocation was not used. The test was performed under the supervision of a pediatrician to avoid potential complications. The test results were evaluated by making double comparisons within each group, between groups, and triple comparisons between three groups. In addition, the test duration was compared in three different periods for each group.

1-First 15 min: To obtain basal values in the supine position,

2-Between the 15th and 45th minutes: To obtain the response in the early period of standing,

3-Between the 45th and 65th minutes: To obtain the response in the late period of standing.

Statistical Analysis

The data obtained were provided using SPSS for Windows 11.0. Kruskal-Wallis and Mann-Whitney U tests were used for comparisons between the groups. A p-value 0.05 was considered significant.

Results

Fifteen basketball players, 15 wrestler children, and 15 healthy children of similar age and gender who do not play sports regularly were included in the study. The children were all boys. The average age of those involved in wrestling sports was 15.40±0.73, the average age of those involved in basketball sports was 12.26±0.79, and the average age of the control group was 13.26±1.43. None of the participating children had a history of syncope in themselves or in their families. When all three groups were compared separately as the basal rest period in the first 15 min, the early period of standing between the 15th and 40th min, and the late period of standing between the 40th and 65th min, cardiac pulse values throughout the entire test period were lowest in wrestlers and slightly higher in basketball players. It was found to be higher and statistically significantly higher in the control group than in the other two athlete groups. No significant difference was detected in terms of systolic and diastolic blood pressure (Table 1).

When the control, basketball player, and wrestler groups were compared separately in the first 15 min, between 15 and 40 min, and between 40 and 65 min, the cardiac pulse values during the basal rest period were significantly lower than the values in the early and late periods of the standing period. Additionally, there was no significant difference between cardiac pulse values in the standing position.

When the control, basketball player, and wrestler groups are compared in terms of systolic blood pressure values during the basal rest period and the early and late periods of the standing period, the difference between them is not significant.

There was no difference in the control group in terms of diastolic blood pressure values during the basal rest period and the early and late periods of the standing period.

When the basketball player and wrestler groups were compared in terms of the parts of the test, the diastolic blood pressure values measured during the basal rest period were found to be significantly lower than those measured during both the 2nd and 3rd parts of the test. However, the difference between the second and third parts of the test was not statistically significant.

When the control group and the basketball player group were compared separately in terms of cardiac pulse values during the basal rest period, the early period of standing, and the late period of standing, there was no statistically significant difference in the basal rest period and the early period of standing. However, during the late period of standing, pulse values in the control group were significantly higher than those playing basketball (p=0.01).

When the control group and the basketball player group were compared separately in terms of systolic and diastolic blood pressure values during the basal rest period, the early period of standing, and the late period of standing, it was observed that there was no significant difference between them.

Table 1. Comparison of the groups in all three test sections				
		n=15 (each group)	Median ± SD	p
0-15th minute	Cardiac pulse values	Control	86.4±6.7	0.015*
		Basketball players	84.0±9.3	
		Wrestlers	76.7±10.4	
	Systolic BP	Control	108.2±6.5	0.07
		Basketball players	110.7±6.7	
		Wrestlers	114.0±2.0	
	Diastolic BP	Control	66.5±4.6	0.07
		Basketball players	64.8±4.5	
		Wrestlers	62.0±5.7	
15-40th minute	Cardiac pulse values	Control	93.1±2.0	0.005*
		Basketball players	90.0±5.5	
		Wrestlers	83.8±10.2	
	Systolic BP	Control	109.8±6.2	0.45
		Basketball players	110.9±5.3	
		Wrestlers	113.0±2.6	
	Diastolic BP	Control	67.1±3.6	0.18
		Basketball players	68.1±3.6	
		Wrestlers	66.6±5.8	
40-60th minute	Cardiac pulse values	Control	93.4±2.4	0.00*
		Basketball players	88.8±7.2	
		Wrestlers	84.8±7.7	
	Systolic BP	Control	110.0±5.7	0.06
		Basketball players	111.5±4.0	
		Wrestlers	113.6±2.3	
	Diastolic BP	Control	66.9±1.9	0.12
		Basketball players	68.1±2.8	
		Wrestlers	66.3±3.4	

SD: Standard deviation, BP: Blood pressure; *Kruskal-Wallis and Mann-Whitney U tests were used to compare all three groups. A p-value 0.05 was considered significant

When the control group and the wrestler group were compared separately in terms of cardiac pulse values during the basal rest period, the early period of standing, and the late period of standing, the cardiac pulse values of the wrestlers were found to be significantly lower than those of the control group during the entire test period (p=0.002, 0.0005, 0.00 respectively).

When the control group and the wrestler group were compared separately in the first 15 minutes, 15th-40th minutes and 40th-65th minutes, the systolic blood pressure values of the wrestlers were found to be significantly higher than the control group during the basal rest period and in the late period of standing (p=0.01, 0.018 respectively). However, there was no significant difference between the 15th and 40th minutes between the two groups.

When the control and wrestler groups were compared separately during the three periods of the test, the diastolic blood pressure values of the wrestlers were found to be significantly lower than those of the control group during the basal rest period (p=0.03). However, there was no significant difference in the standing period.

When the basketball player group and the wrestler group were compared in terms of cardiac pulse throughout the entire test period, the wrestlers' cardiac pulse was found to be significantly lower than that of the basketball player group throughout the entire test (p=0.02, 0.02 and 0.04, respectively).

When the basketball player and wrestler groups were compared, there was no significant difference between the groups in terms of systolic and diastolic blood pressure values during the three periods of the test.

Discussion

The head-up tilt test was used to compare the responses of children performing isometric and isotonic sports to orthostatic position change. During the entire test, the wrestlers' pulse rates were lower. Simultaneously, during the basal rest period at the beginning of the test, the wrestlers' systolic blood pressure values were found to be high and their diastolic blood pressure values were low, and at the end of the test, systolic blood pressure remained high.

The tilt table test is used as a very effective test in the evaluation of patients with vasovagal syncope triggered by orthostatic change[10]. It is an effective technique for direct diagnosis in the sensitive evaluation of vasovagal syncope[11]. The most important problem in position changes is orthostatic intolerance, which develops because of the autonomic characteristics of bipedal creatures when they become upright. Orthostatic intolerance refers to the development of symptoms (temporary loss of consciousness and/or postural tone) when moving from a lying position to a standing position[1,10,11]. When we stand up, the veins below the heart level fill with blood, the return to the heart decreases, and cerebral perfusion decreases because of the hydrostatic pressure in the blood[11]. When we stand up, the rapid decrease in the amount of blood flowing to the brain due to the pooling of blood in the large veins due to the position of the brain above the cardiac point and the gravity below it causes cerebral ischemia and loss of consciousness[12]. In response to blood pooling in the lower extremities, the muscles act as pumps and return the blood to the heart. During orthostatic changes, reflex compensatory mechanisms cause changes in heart rate and vasoconstriction[13]. In later stages, defense against cerebral hypoperfusion can be established through the release of renin-angiotensin-aldosterone, the release of epinephrine and norepinephrine, and the initiation of the central effect.

The exercises that people perform in their daily lives include a combination of dynamic and static exercises. The systemic cardiovascular response depends on whether muscle contractions are primarily isometric or isotonic. The heart rate increases with isometric muscle contraction. This increase in heart rate is largely dependent on decreased vagal tone, although increased cardiac sympathetic nerve discharge also plays a role. During isometric muscle contraction, systolic and diastolic blood pressures rise sharply. Stroke volume changes relatively less, and blood flow to the constantly contracting muscles decreases because of their pressure on the blood vessels. The response to exercise involving isotonic muscle contraction is similar to the situation described above in that there is a sudden increase in heart rate, but unlike these, there is also a significant increase in stroke volume. In addition, there was a clear decrease peripheral resistance due to vasodilation in the exercising muscles. As a result, systolic blood pressure increased moderately, whereas diastolic blood pressure generally remained unchanged or decreased. Mean arterial pressure increases because cardiac output increases because of the decrease in total peripheral pressure[9].

In the head-up tilt test, the response to normal heart rate and blood pressure is an increase in heart rate by 10-20 beats per minute. The increase in systolic blood pressure was not very significant. Diastolic pressure and mean arterial pressure increase to some extent, thus reducing the pulse pressure. These changes occur because of the rapid displacement of blood to the lower extremities and are a normal response. Most studies recommended that the angle be 60-70 degrees and found the specificity to be 90% and the sensitivity to be 67-83% in the absence of pharmacological agents[14,15]. In studies conducted by Fitzpatrick et al.[16], it was suggested that the tilt duration should be 45 min. They found the average time for syncope to occur to be 24 min. They point out that the 40-min tilt duration is more useful in detecting syncopal attacks than the 30-min tilt test, but extending the test further and continuing up to 60 min increases the sensitivity only slightly[17]. In our study, following the 15-min basal period, the tilt table was turned to 70° and the test duration was determined as 65 min. Pharmacological provocation was not applied because of its negative effect on test specificity.

Because of the study, when the three groups were compared, it was observed that the cardiac pulse values of the wrestlers were lower than those of the basketball players, and the cardiac pulse values of the basketball players were lower than those of the control group throughout the entire test. These basal values can be explained by the fact that the heart rate in athletes is lower than that in those who do not participate in sports. In addition, the fact that the heart rate in wrestlers, that is, people who do dominantly isometric exercise, is lower than that in both basketball players and the control group can be attributed to the increase in total peripheral resistance in isometric exercise and the lower amount of blood returning to the heart due to the effect of the muscles contracting on the blood vessels.When the control group, basketball player group, and wrestler group were compared among themselves, a statistically significant increase was observed in the cardiac pulse values in the first 15 min after removing the tilt table. This increase was 7.75% in the control group, 7.1% in the basketball player group, and 9.2% in the wrestler group. This is the normal response of the head-up tilt test. This is an expected response that occurs due to the change in the amount of blood pooled in the lower extremities returning to the heart upon standing up.

In a study by Mallat et al.[18], it was pointed out that this early increase in heart rate in the tilt test is an important harbinger of the test being positive, whereas Newby et al.[19] stated that their own observations were not in this direction. Another study on the subject supports the predictive importance of the early increase in heart rate on the positivity of the test. In other words, while the test results in vasovagal syncope in people who have an increase in heart rate in the early stages of standing up, there are also researchers who found the opposite of this view in their studies[18-20].

In our study, the heart rate increased upon standing in all groups. This situation, which has been evaluated in favor of a positive test in various studies, was also encountered in our study, but the test did not result in a positive result in the control, basketball player, and wrestler groups included in the study. When the control and basketball player groups were compared, a significant decrease in pulse values was observed in the basketball player group toward the end of the test period. However, when the basketball player group was compared among themselves, pulse values were found to be low only in the first 15 min. Therefore, it would be wrong to talk about a decrease in the heart rate of basketball players toward the end of the test period.

In pairwise comparisons between the groups, while there was no significant difference between the basketball player group and the control and wrestler groups, when the control group and the wrestlers were compared, it was determined that the systolic blood pressure values in the wrestler group were significantly higher than those in the control group, both during the basal rest period and during the remaining test period. This was a response consistent with high systolic blood pressure during predominantly isometric exercise. In the head-up tilt test, an increase in systolic blood pressure upon standing up was expected. However, such an increase or decrease was not observed in any group in our study.

When a comparison was made between the groups in terms of diastolic blood pressure values, diastolic blood pressure values were found to be significantly lower in the basketball player and wrestler groups during the first 15 min compared with the subsequent test period. However, there was no significant difference between the diastolic blood pressure values of the control, basketball, and wrestler groups when compared separately and together. While the basal diastolic blood pressure increased by 5.0% upon standing in the basketball player group, this value was 7.4% in the wrestler group. This increase is compatible with the response to the displacement of blood in the body upon standing up.

There are important differences between dynamic and static muscle contractions. One of the most important of these relates to blood supply to the muscles. In static muscle contractions, blood vessels work under great pressure because of the continuous contraction effect in the muscles. This causes less and less blood to be sent to the muscles. In dynamic contraction, there is a positive effect on blood circulation as muscle movement contract and relax rhythmically. During contraction, blood reaches the ends of the capillaries that feed the muscle fibers, allowing 10-20 times more blood to reach these places. Therefore, during dynamic muscle contraction, the muscle receives plenty of glucose and oxygen, and wastes can be eliminated immediately. During strong static muscle contraction, neither glucose nor oxygen reaches the muscle. In addition, waste accumulates and is not eliminated from the muscle. Therefore, it is very difficult to withstand long-term static muscle contraction. Because the feeling of pain occurs because of these wastes. If a suitable rhythm is provided for dynamic muscle contraction, it can be continued for a long-time without any wear and tear (for example, heart muscles). During static muscle contraction, blood transport decreases inversely proportional to contraction. When the applied muscle force reaches 60% of the maximum muscle force, blood flow is completely cut-off. In lower muscle force applications, because there is less pressure on the blood vessels, some blood circulation can be achieved. During a muscle contraction of 15-20% compared with maximum loading, blood flow to the muscle is normal. While a muscle contraction of 20% can be sustained for a long time, a muscle contraction of 50% or more can be sustained for at most 1 min. Therefore, activities that result in continuous static muscle contraction are not desirable.In a study conducted by Croci et al.[21], who investigated the effect of isometric hand gripping movement in preventing vasovagal syncope during daily life, based on the fact that isometric hand grasping movement increases blood pressure in the initial phase of vasovagal syncope, patients were made to perform hand gripping or arm stretching movements when they experienced the symptoms in the initial phase of syncope. This effect is caused by mechanical compression of the venous vascular bed in the abdomen and legs and by increased vascular resistance and sympathetic discharge during maneuvers. Therefore, it is recommended as the first treatment option in the initial stages[21].

Isotonic exercise (treadmill and bicycle) is often used to determine tolerance to exercise. However, static exercise occurs more during daily activities, and therefore, it is necessary to compare the two. In a study conducted for this purpose to determine the cardiovascular responses to static and dynamic exercise in patients with non-valvular atrial fibrillation, the exercise tolerance of the patients was investigated. The patients were given treadmill exercise as a dynamic (isotonic) exercise and hand grasping exercise as a static (isometric) exercise. When the heart rate values at the first, second, and third minutes of the exercise were compared, it was found to be significantly higher on the treadmill than in manual gripping. When the systolic and diastolic blood pressures at the 1st minute were compared, higher values were obtained on the treadmill. As a result, it was observed that the heart rate response of the patients to static exercise was lower and the patients tolerated the static exercise better[22].

In some people, orthostatic intolerance to body position changes is a major problem. Because of our study, there was a greater increase in diastolic blood pressure upon standing up in those who performed isometric-based wrestling compared with those who performed isotonic-based sports. This suggests that isometric weighted movements should be performed more frequently to prevent orthostatic intolerance, which is the most common cause of vasovagal syncope.

Study Limitations

The strength of our study is that it will contribute to the limited literature by evaluating the responses of young male athletes who perform isometric and isotonic sports to the tilt table test. Its limitations are that it was performed only on male athletes, no pharmacological provocation was used, and the number of participants was relatively small.

Conclusion

As a result, although the effects of dynamic exercise on the cardiovascular system are more positive, studies have shown that isometric muscle movements are beneficial, especially in the initial stage of vasovagal syncope. However, the effect of isometric and isotonic contraction on the cardiovascular system and orthostatic position changes in people is worth investigating.

Ethics

Ethics Committee Approval: Ethical approval for the study was obtained (Manisa Celal Bayar University Faculty of Medicine, 2005/0001).

Informed Consent: After the subjects were informed about follow-up, a written consent form was signed.

Footnotes

Authorship Contributions

Concept: C.B., S.B.Y., Ş.C., Design: C.B., S.B.Y., Ş.C., Data Collection or Processing: C.B., S.B.Y., Ş.C., Analysis or Interpretation: C.B., S.B.Y., Literature Search: C.B., S.B.Y., Writing: C.B., S.B.Y., Ş.C.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Astrand PO, Rodahi K. Textbook of Work Physiology. McGraw-Hill Book Co. Third Ed. 1998.
2. American Autonomic Society, American Academy of Neurology: Consensus statement on the definition of orthostatic hypotension, pure autonomic failure, and multiple system atrophy. The Consensus Committee of the American Autonomic Society and the American Academy of Neurology. Neurology. 1996;46:1470.
3. Kenny RA, Ingram A, Bayliss J, Sutton R. Head-up tilt: a useful test for investigating unexplained syncope. Lancet. 1986;1:1352-5.
4. Abi-Samra F, Maloney JD, Fouad-Tarazi FM, Castle LW. The usefulness of head-up tilt testing and hemodynamic investigations in the workup of syncope of unknown origin. Pacing Clin Electrophysiol. 1988;11:1202-14.
5. Almquist A, Goldenberg IF, Milstein S, et al. Provocation of bradycardia and hypotension by isoproterenol and upright posture in patients with unexplained syncope. N Engl J Med. 1989;320:346-51.

6. Fitzpatrick A, Sutton R. Tilting towards a diagnosis in recurrent unexplained syncope. Lancet. 1989;1:658-60.
7. Miyamoto Y, Nakazono Y, Yamakoshi K. Neurogenic factors affecting ventilatory and circulatory responses to static and dynamic exercise in man. Jpn J Physiol. 1987;37:435-46.
8. Kahn JF, Jouanin JC, Colomb F, Huart F, Monod H. Complementary roles of central command and muscular reflex in the regulation of heart rate during submaximal isometric contraction. Electromyogr Clin Neurophysiol. 1992;32:3-10.
9. Seals DR, Chase PB, Taylor JA. Autonomic mediation of the pressor responses to isometric exercise in humans. J Appl Physiol (1985). 1988;64:2190-6.
10. Raviele A, Gasparini G, Di Pede F, Delise P, Bonso A, Piccolo E. Usefulness of head-up tilt test in evaluating patients with syncope of unknown origin and negative electrophysiologic study. Am J Cardiol. 1990;65:1322-7.
11. Thilenius OG, Quinones JA, Husayni TS, Novak J. Tilt test for diagnosis of unexplained syncope in pediatric patients. Pediatrics. 1991;87:334-8.
12. Farquhar WB, Taylor JA, Darling SE, Chase KP, Freeman R. Abnormal baroreflex responses in patients with idiopathic orthostatic intolerance. Circulation. 2000;102:3086-91.
13. Pitzalis M, Massari F, Guida P, et al. Shortened head-up tilting test guided by systolic pressure reductions in neurocardiogenic syncope. Circulation. 2002;105:146-8.
14. Qingyou Z, Junbao D, Jianjun C, Wanzhen L. Association of clinical characteristics of unexplained syncope with the outcome of head-up tilt tests in children. Pediatr Cardiol. 2004;25:360-4.
15. Streeten DH, Scullard TF. Excessive gravitational blood pooling caused by impaired venous tone is the predominant non-cardiac mechanism of orthostatic intolerance. Clin Sci (Lond). 1996;90:277-85.
16. Fitzpatrick AP, Theodorakis G, Vardas P, Sutton R. Methodology of head-up tilt testing in patients with unexplained syncope. J Am Coll Cardiol. 1991;17:125-30.
17. Stein KM, Slotwiner DJ, Mittal S, Scheiner M, Markowitz SM, Lerman BB. Formal analysis of the optimal duration of tilt testing for the diagnosis of neurally mediated syncope. Am Heart J. 2001;141:282-8.
18. Mallat Z, Vicaut E, Sangaré A, Verschueren J, Fontaine G, Frank R. Prediction of head-up tilt test result by analysis of early heart rate variations. Circulation. 1997;96:581-4.
19. Newby DE, Flint LL, El Hag O. Heart rate increases in tilt test. Circulation. 1998;98:187-8.
20. Sumiyoshi M, Nakata Y, Mineda Y, et al. Does an early increase in heart rate during tilting predict the results of passive tilt testing? Pacing Clin Electrophysiol. 2000;23:2046-51.
21. Croci F, Brignole M, Menozzi C, et al. Efficacy and feasibility of isometric arm counter-pressure manoeuvres to abort impending vasovagal syncope during real life. Europace. 2004;6:287-91.
22. Ifuku H, Shiraishi Y. Assessment of cardiovascular regulation during head-up tilt and suspension in swimmers. Med Sci Sports Exerc. 2004;36:155-9.