Importance of Peak Height Velocity Timing in Terms of Injuries in Talented Soccer Players

Article *in* International Journal of Sports Medicine · January 2015

DOI: 10.1055/s-0034-1385879 · Source: PubMed

Importance of Peak Height Velocity Timing in Terms of Injuries in Talented Soccer Players

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Key words
- maturation
- development
- traumatic
- overuse
- longitudinal study
- adolescent

Abstract

The purpose of this study was to identify differences in traumatic and overuse injury incidence between talented soccer players who differ in the timing of their adolescent growth spurt. 26 soccer players (mean age 11.9±0.84 years) were followed longitudinally for 3 years around Peak Height Velocity, calculated according to the Maturity Offset Protocol. The group was divided into an earlier and later maturing group by median split. Injuries were registered following the FIFA consensus statement. Mann-Whitney tests showed that later maturing players had a significantly higher overuse injury incidence than their earlier maturing counterparts both in the year before Peak Height Velocity (3.53 vs. 0.49 overuse injuries/1 000 h of exposure, $U=49.50$, $z=-2.049$, $p<0.05$) and the year of Peak Height Velocity (3.97 vs. 1.56 overuse injuries/1 000 h of exposure, $U=50.5$, $z=-1.796$, $p<0.05$). Trainers and coaches should be careful with the training and match load they put on talented soccer players, especially those physically not (yet) able to handle that load. Players appear to be especially susceptible to injury between 13.5 and 14.5 years of age. Training and match load should be structured relative to maturity such that athletic development is maximized and the risk of injury is minimized.

Introduction

The topic of size and maturity mismatch in youth sports has been discussed for a long time in relation to unfair competitive advantages and to the risk of injury [21]. As a group, talented adolescent soccer players are advanced in maturity compared to the general population [23], and the number of late maturing players decreases in the chronologically older selection groups of talent development programs in soccer [11, 28, 35]. This indicates an advantage in being selected for these programs on the part of early maturing players. It has been mentioned that coaches and scouts give preference to players of greater size and power in talent development programs, which leads to the exclusion of their potentially talented peers who are smaller and have less strength and power due to a later timing in their maturation [22]. Another plausible factor that might play a role in the disadvantageous position of late maturing players is a heightened vulnerability to injuries.

The most commonly used indicators of maturation include skeletal age (SA) and secondary sex characteristics (pubic hair, genitals, testicular volume). Age at peak height velocity and percentage of mature (adult) height attained at a given age are minimally invasive, feasibly practical indicators of somatic maturation [2]. Due to the differences in biological maturation, there is considerable variation in size and power of adolescent soccer players [6, 11]. Players more advanced in biological maturation tend to be taller, heavier, stronger and faster than players who are more delayed in maturation [7, 12, 17, 25]. In the study of Figueireido et al. (2010) the differences in average height and weight between the least and most mature players in the same age group (13–14 years old) are 15 cm and 21 kg, respectively, and the difference in skeletal age (Fels method) is as great as 3.7 years [11]. The early maturing players score significantly better on power and agility tests. In addition, late maturing players might have an extra disadvantage due to a supposed temporary decrease in motor skills performance during PHV [32] occurring just as early maturing players in the same age group are already past their PHV. Taken together, this mismatch in height, weight, power, speed and agility between players in the same chronological age group possibly results in a game dominated by boys who are advanced in

accepted after revision
June 02, 2014

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DOI http://dx.doi.org/10.1055/s-0034-1385879
Published online: January 21, 2015
Int J Sports Med 2015; 36: 327–332 © Georg Thieme Verlag KG Stuttgart · New York
ISSN 0172-4622

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maturity. For later maturing players, this may result in a higher risk for traumatic injuries, as has been mentioned by some authors [21,34]. Still, evidence is not consistent [1,9,18,20].

Late maturing players may also run an increased risk of overuse injuries. In soccer, the training load intended by coaches is often referred to as the external load [16]. The actual amount of physiological stress experienced by an individual athlete during training and competition, often referred to as internal training load, is determined by the external training load and individual factors, such as training status or (maturity-associated) endurance [16]. Talent development programs should be maximizing individual development, while minimizing the risk of injury. However, whether this is actually the case remains unknown. Training programs are scheduled according to chronological age group and not, for example, maturity category. Over these chronological age groups, the external training load increases [8,37]. The same training stimulus may improve performance in one player, maintain performance in another and cause injuries in a third player [19]. Late maturing players may be exposed to a higher internal training load since their physical capacities are less developed compared to early maturing players, making them more prone to injuries.

The same possibly applies for match-play: the total distance, high-intensity distance, and very high intensity distance that players cover increase with older ages [14], the same being true for acceleration, maximum running speed and repeated sprint ability [29]. Some studies have analyzed differences in injury occurrence between early and late maturing soccer players (e.g., [18,27]), without, however, always yielding clear results. Recently we conducted a study in which we focused on differences in injury occurrence in talented pubertal soccer players during different phases of maturation (before, during and after PHV). We concluded that players were more vulnerable to traumatic injuries during PHV [36], and suggested that this might be even more the case for later maturing players. As far as the authors know, no studies have looked at injury occurrence during different phases of maturation aligned to the timing of peak height velocity. Furthermore, the mechanisms that cause traumatic and overuse injuries could well be different. Studies concerning injuries in early and late maturing players have so far mainly examined match and training injury incidence (e.g., [20]) and have made no distinction in type of injury (traumatic vs. overuse). Information on differences in traumatic and overuse injury incidence, injury location and severity would contribute to having a grasp of the injury incidence associated with maturity status.

The purpose of this study is therefore to follow talented soccer players who differ in the timing of their peak height velocity longitudinally for 3 years around peak height velocity and to identify differences in traumatic and overuse injury incidence. We hypothesize that later maturing players have a higher risk of both traumatic and overuse injuries.

Material and Methods

Participants

In an earlier study we followed a group of soccer players for 3 years around peak height velocity to identify differences in injury occurrence during those measurement periods [36]. Because of the presumption that the disadvantage from injury occurrence would be even greater for later maturing players, in the current study we stratified the same data in a different way to focus on differences between those players maturing at a younger and at an older age. Participants were soccer players in a Dutch professional soccer club, competing at the highest level of their age category and therefore belonging to the best 0.5 % of the total number of players in their age group (National Soccer Association, KNVB). They were selected for the talent development program by the scouts, trainers and staff of the professional soccer club. Only those players who had been participating in the talent development program of the club for at least 3 years around their PHV (1 year before, 1 year during and 1 year after PHV) were included. As a consequence, players were excluded if they dropped out of the program during one of the 3 years, or if they reached peak height velocity within 1.5 years after their selection for the talent development program (after all, these players could not be followed during their complete year before PHV, because this year runs from 0.5 to 1.5 years before PHV). Of the approximately 120 players who were selected to participate for at least 1 year in the talent development program for the study period of 4 consecutive years, 26 of these met all the inclusion criteria and were included in the study.

Peak height velocity

In order to divide the group into players maturing at younger and older ages, the algorithm derived from 2 longitudinal studies of Canadian youth and one of Belgian twins was used to predict the time in years the soccer players spent in a state before PHV, termed maturity offset ($R=0.94$, $R^2=0.89$, and $SEE=0.59$) [28]. For males, equation 3 was used, which calculates maturity offset as follows: $-9.236+(0.0002708*(\text{leg length}*\text{sitting height}))+(-0.001663*(\text{age}*\text{leg length}))+(0.007216*(\text{age}*\text{sitting height}))+(0.02292*(\text{weight}/\text{height}*100))$. The standard deviation of the combined sample was estimated as 0.9 years [24], and is mainly applicable and accurate for boys measured during the interval of the growth spurt (12–15 years) and who are undergoing maturation on time [26].

The anthropometric data for the equation were collected as follows: height was measured to the nearest millimeter, with a body length meter (Schinkel Medical, Nieuwegein, the Netherlands) that was fixed on a wall. Boys stood erect without shoes, their heels together and with their head in the Frankfort horizontal plane [33]. Sitting height was measured from the ground to the head, while players sat on a table with a straight back against the wall. By subtracting the height of this table from the measured height, sitting height was calculated. Leg length was calculated by subtracting the sitting height from the total height (i.e., height of players while they were standing against a wall). Weight was measured using an analogue scale to the nearest 0.1 kg. All measurements were taken at the end of the season and were carried out by skilled testers.

After calculating maturity offset, predicted age at PHV was estimated as chronological age (CA) plus maturity offset. The group of players was then divided in 2 by median split based on this predicted age at PHV, resulting in 13 players who had their PHV at an earlier age (moment of PHV between age 12.85 and 13.91) and 13 players who had their PHV at an older age (moment of PHV between age 13.92 and 15.41).

The groups were heterogeneous in height and weight at the time of their first selection, with a mean height of 158.2 ± 9.3 cm and a mean weight of 46.4 ± 7.2 kg for the group maturing at an older age and a mean height of 155.8 ± 9.1 cm and a mean weight of 45.9 kg ± 9.5 cm for the group maturing at a younger age.

Both groups were followed for 3 years around PHV (1 year before, 1 year during and 1 year after). The year of PHV was set by taking 6 months before and 6 months after predicted age at PHV. The 12 months before this year of PHV were assigned as the year before PHV (Pre-PHV), the 12 months after the year of PHV were assigned as the year after PHV (Post-PHV).

Injury data

The club physician diagnosed and recorded injuries during the period in which the soccer players were in the talent development program. The definitions and data-collection procedures that were used follow the recommendations of the consensus statement for soccer injury studies, i.e., the FIFA registration system [13]. An injury was defined as: “any physical complaint sustained by a player that results from a soccer match or a soccer training, irrespective of the need for medical attention or time loss from soccer activities”. Injuries were reported if a player was unable to take full part in future soccer training or match play for at least 24 h (time loss injuries) or if a player needed medical attention, but was still able to take part in training or competition (medical attention injuries). Traumatic injuries were defined as injuries that resulted from a specific, identifiable event. Overuse injuries were defined as injuries that resulted from repeated micro trauma without a single identifiable event. Injuries were classified according to location, type, mechanism and severity of the injury. Defined in terms of the number of days that the player was not able to take full part in competition or training sessions, the severity of the injury was deemed slight (no absence from training session or match, also recorded as “medical attention injury”), minimal (1–3 days time loss), mild (4–7 days time loss), moderate (8–28 days time loss), severe (more than 28 days time loss) and career-ending injuries.

Calculation of exposure and injury incidence

Information on training and match hours in the 3 measurement periods was gathered through a questionnaire that players completed for research purposes and checked against the actual amount of training and match time as provided by the club. In case of missing data, training and match hours were replaced by the average amount of training hours or match hours for the corresponding age category in that year. Traumatic and overuse injury incidence were calculated for the 3 measurement moments (year before PHV, year of PHV and year after PHV) as the number of traumatic/overuse injuries/1 000-h exposure to training sessions and competition.

Statistical analysis

SPSS 20.0 was used to analyze the data. Descriptive statistics (means and standard deviations) for age, training hours and match hours along with traumatic and overuse injury incidences were calculated for the 2 groups (reaching their PHV at earlier or older ages) for each measurement period (year before, year during or year after peak height velocity). The normality of the distributions of traumatic and overuse injury incidence for the 2 groups (players maturing at a younger and players maturing at an older age) at the 3 different periods (Pre-PHV, PHV and Post-PHV) was tested using Kolmogorov-Smirnov tests. P-values lower than 0.05 were considered to be significant, which was the case for almost all variables, indicating that the variables were not normally distributed. It was therefore not possible to perform a mixed design ANOVA (GLM 5) or unpaired sample t-tests. Differences in injury incidence between the 2 groups were tested using Mann-Whitney tests [10]. All p-values were two-tailed and significance level was set at $p < 0.05$.

The study meets the established ethical standards for sports medicine [15]. An institutional agreement was signed between the Center for Human Movement Sciences of the University of Groningen and the soccer club to ensure data collection.

Results

The mean age at PHV was 14.04 (±0.65) years for the whole group (▸ **Table 1**). This means that on average, their year of PHV took place from 13.54 until 14.54 years of age, which translates from 6 months before the moment of PHV until 6 months after. The group maturing at a younger age had a mean age at PHV of 13.50 (±0.34), while the later maturing group had a mean age at PHV of 14.52 (±0.44). The player with the earliest age at PHV had an age at PHV of 12.85 years, while the player with the latest age at PHV had an age at PHV of 15.41. ▸ **Table 1** also provides exposure time for both groups at the 3 measurement periods.

Over the total measurement period, 178 injuries were recorded among the 26 players, 67 in the group of players maturing at a younger age (PHV < 13.92) and 111 in the group of players maturing at an older age (PHV ≥ 13.92). ▸ **Fig. 1** shows the locations of traumatic and overuse injuries in both groups. Players maturing at a younger age had 39 traumatic and 28 overuse injuries over the measurement period of 3 years, compared to 51

Table 1 Mean age in the year of PHV and exposure time (training and match hours) per year in the 3 measurement periods (pre-PHV, PHV and post-PHV) for players maturing at a younger age and players maturing at an older age.

	Mean age in year of PHV	Exposure time pre-PHV	Exposure time PHV	Exposure time post-PHV
group maturing at younger age (PHV < 13.92, n = 13)	13.50 ± 0.34	428.53	426.11	413.25
group maturing at older age (PHV ≥ 13.92, n = 13)	14.52 ± 0.44	403.45	430.94	484.56

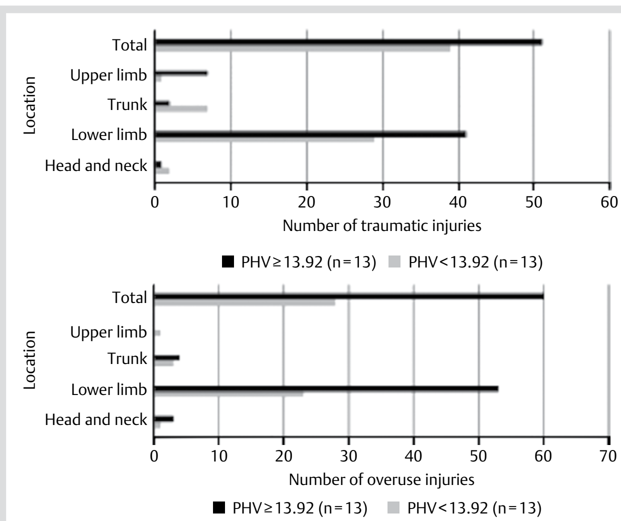

Fig. 1 Injury locations for traumatic and overuse injuries in players maturing at a younger and older age.

Table 2 Incidences of traumatic and overuse injuries in 3 years around PHV, for players maturing at a younger and older age. Scores are represented as number of injuries per 1 000 h of exposure (training and competition).

	Group maturing at a younger age (PHV < 13.92, n = 13)	Group maturing at an older age (PHV ≥ 13.92, n = 13)	Effect size *r*
traumatic injuries			
incidence of traumatic injuries pre-PHV	1.14 ± 1.97	2.33 ± 3.40	0.18^{+}
Incidence of traumatic injuries PHV	3.14 ± 3.52	3.96 ± 2.57	$0.21^{\#}$
incidence of traumatic injuries post-PHV	2.95 ± 3.59	2.97 ± 3.74	0.03^{+}
overuse injuries			
incidence of overuse injuries pre-PHV	0.49 ± 0.94 *	3.53 ± 4.63 *	0.40^
incidence of overuse injuries PHV	1.56 ± 1.92 *	3.97 ± 3.11 *	$0.35^{\#}$
incidence of overuse injuries post-PHV	2.73 ± 3.84	3.60 ± 2.73	$0.24^{\#}$

$r = 0.10$ (small^{+}), d = around 0.30 (medium$^{\#}$), d = around 0.50 (large^); * $p < 0.05$

traumatic injuries and 60 overuse injuries in the group of players maturing at an older age.

In terms of overuse injuries, the greatest difference between players maturing at a younger or older age can be seen in injuries located in the lower limb, mostly those located in the knee. Players maturing at a younger age had 7 overuse injuries located in the knee compared to 23 in the group of players maturing at an older age. These knee injuries were diagnosed as Osgood-Schlatter disease in 3 players from the group maturing at a younger age and in 4 players maturing at an older age. However, there was remarkable difference between these 2 groups in terms of the days missed from training sessions and competition due to this diagnosis: in the group of players maturing at a younger age 15 days of training and competition were missed compared to 58 in the group of players maturing at an older age.

Table 2 shows the mean incidences per 1 000 h of exposure for traumatic and overuse injuries in the 2 groups for the 3 different measurement periods (the year before PHV, the year of PHV and the year after PHV). In both groups, the incidence of traumatic injuries increases from the year before PHV to the year of PHV, and then decreases thereafter. In terms of overuse injuries, these injuries increase from the year before PHV to the year of PHV and further increase in the year after PHV in the group of earlier maturing players. For the group of players maturing at an older age, overuse injury incidence in the year before PHV is 7 times higher than the earlier maturing group and increases only slightly in the year of PHV. The highest injury incidence was found for overuse injuries in the year of PHV (3.97 ± 3.11) in players maturing at an older age, followed by traumatic injury incidence in the year of PHV for the same group (3.96 ± 2.57). The Mann-Whitney test showed a significant difference in overuse injuries in the year before PHV and the year of PHV. Players who had their PHV at an older age had a higher incidence of overuse injuries before PHV ($U = 49.50$, $z = -2.049$, $p < 0.05$, $r = 0.40$) and during PHV ($U = 50.5$, $z = -1.796$, $p < 0.05$, $r = 0.35$).

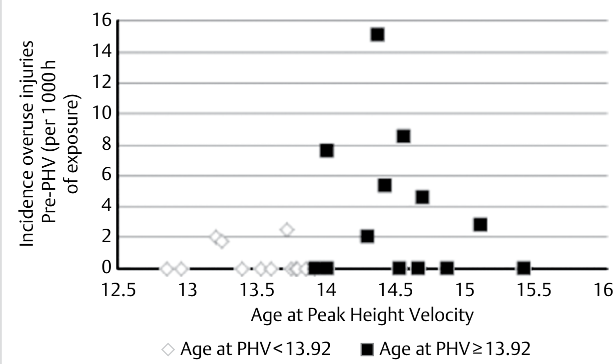

Fig. 2 Age at peak height velocity and incidence of overuse injuries in the year before PHV.

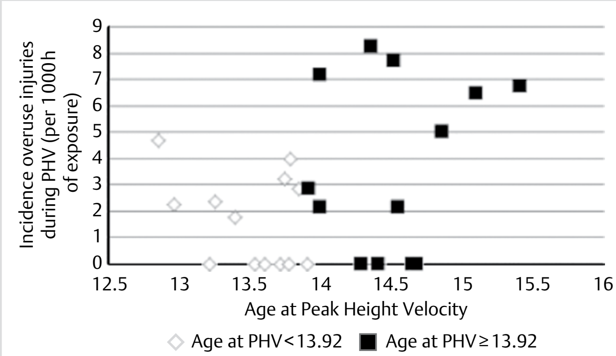

Fig. 3 Age at peak height velocity and incidence of overuse injuries in the year of PHV.

The relationship between age at PHV and individual incidence of overuse injuries is graphically displayed in **Fig. 2, 3**. **Fig. 2** displays the individual overuse injury incidence before PHV and the age at which the individual players experience their PHV. Players in the 2 groups are presented using different colors. In **Fig. 3**, the same is done for the individual overuse injury incidence during PHV.

Discussion

The purpose of this study was to follow talented soccer players who differ in the timing of their peak height velocity longitudinally for 3 years around their PHV and to identify differences in traumatic and overuse injury incidence.

In general, the injury problem as a whole seems to increase from the year before PHV to the year of PHV for both earlier and later maturing groups. Traumatic and overuse injury incidence increases from the year before PHV to the year of PHV. The results of the current study show that talented soccer players maturing at an older age experience significantly more overuse injuries than their earlier maturing counterparts, both before PHV and during PHV. In earlier studies, no clear difference in injury rates was found between early, on-time and late maturing players [18,20,27]. However, those studies mostly looked at differences in injuries during one competitive season. The approach of the current study provides more detailed insight into differences in injury incidence between players maturing at younger and older ages in 3 individually determined, consecutive maturation periods of 1 year. This provides more information on specific moments during development in which players are vulnerable.

The players maturing at an older age experience an incidence of overuse injuries pre-PHV that is 7 times higher than their earlier maturing counterparts in the same maturation period. Apparently, the later maturing players experience a period in their talent development process that is "hard to survive". They are surrounded by players who are physically more developed and are therefore taller, heavier and stronger [7,12,25]. Furthermore, because they are chronologically older during their pre-PHV period (and also during their PHV and Post-PHV period) than their earlier maturing counterparts, they are part of a subsequent selection team. As a consequence, they are exposed to a higher external training load and play matches of higher intensity the moment they experience their peak height velocity [8,14,37]. As a result, the internal load that these players experience is possibly higher. A recent study showed that young elite soccer players perceive training as harder than intended by their coach [3]. This may become even more apparent for players who have their PHV at an older age. The internal load that is placed on their later developing bodies is possibly higher than is the case for players who have already experienced their PHV [16] and this may result in a higher incidence of overuse injuries.

Because of the fact that later maturing players are smaller in size, we also expected to find differences in the incidence of traumatic injuries between earlier and later maturing players [34]. However, this difference proved to be not significant. This might be due to the fact that the average magnitude of growth during the year of PHV in this group of players was 6.8 centimeters (7.4 in players maturing at a younger age and 6.2 for players maturing at an older age), which is rather small compared to the magnitude of growth during PHV measured in a study of normal adolescents (10.4 cm per year) [16] and Flemish youth soccer players (9.7 cm per year) [31]. In addition to this, later maturing players were on average taller before they entered the phase of PHV than the earlier maturing players, resulting in a smaller height difference between the 2 groups during the year of PHV of the group maturing at an older age. Furthermore, we followed only those players that were in the talent development program for at least 3 years around their PHV. This selective drop-out of, for example, players with severe injuries or late maturing players may have biased our data. In other words, the mean age at PHV of the players maturing at an older age in the current study is 14.52 years. Most of these players fall within the category of "normal" maturing boys, according to comparable data of Flemish youth soccer players [31]. Of the 26 players we followed for 3 years around PHV, only 2 of them can be defined as "late maturing" (having a skeletal age more than 1 year behind their chronological age). It is possible that the problem of traumatic injuries is greater for players who have skeletal ages that are more than 1 year behind chronological age. A limitation of the current study which may have biased the data is the fact that we used the maturity offset protocol [30] in order to predict age at peak height velocity, which is less precise than, for example, skeletal age as indicator of biological maturation. However, this method has the advantage of being minimally invasive and seems to be valid during the interval of the growth spurt (12–15 years, which is the case for the current study sample) and for boys who are on time (average) in maturation [26]. Of the 26 players in our sample, 23 can be qualified as being on time in maturation.

The fact that we compared injury incidence of players in the same phase of their biological maturation is a strength, but at the same time constitutes a limitation in this study. Players who are in the same phase of biological maturation differ in the chronological age they have attained at that moment. This means that other factors may be influencing the occurrence of injuries, such as the intensity of the training and matches in which they participate. We mentioned that late maturing players might experience a higher internal training load than early maturing players and therefore be more prone to overuse injuries. Past research has shown that individual monitoring of internal training load, stress and recovery can contribute to the prevention of injuries [4,5]. For future research, we would suggest monitoring those factors (e.g., by monitoring heart rate, GPS and session RPE) in order to provide more insight into the difference between players maturing at older and younger age. In addition to this, we would suggest studying the specific injury-related characteristics of players who drop out of talent development programs in soccer.

In conclusion, the results of the current study demonstrate that talented soccer players who mature later than their peers experience a significantly higher overuse injury incidence. This is especially the case in the year before PHV and continues into the year of PHV. Trainers and coaches dealing with talented soccer players should be careful with the training and match load they put on talented soccer players, especially with those who are physically not (yet) able to handle that load. The period between 13.5 and 14.5 years of age appears to be a period in which it is particularly difficult to balance training and match load. Players who mature later are in a vulnerable period before their PHV, whereas players maturing at an earlier age are in the middle of their PHV. This seems to lead to an increased susceptibility to injuries. Training and match load should be structured in such way that maturity is taken into account, athletic development is maximized and the chance of injuries is minimized. This could mean, for example, that internal training and match load are carefully monitored, especially for players maturing at an older age. In case of large differences in internal training load, the earliest and latest maturing players could follow different training schedules, be selected according to different biological age groups or split up in some segments of the training session.

Acknowledgements

The authors would like to thank players and staff for their participation in the study, with a special thanks to Jannes Nijboer, for his contribution to the data collection. Also, we would like thank professor Robert Malina for his constructive feedback concerning the topic.

Conflict of interest: The authors have no conflict of interest to declare.

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Notice
This article was changed according to the following erratum on May 4th 2015.

Erratum
The Manuscript contains an error in Affiliations.
The correct Affiliations are:

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