Cardiac Biomarker Release after Exercise in Healthy Children and Adolescents: A Systematic Review and Meta-analysis

Running head: Cardiac biomarkers after exercise in youth

Abstract

Purpose: We evaluated the impact of acute exercise and 24 h recovery on serum concentration of cardiac troponins (cTnT; cTnI) and NT-proBNP in healthy children and adolescents. We also determined the proportion of participants exceeding the upper reference limits (URL) and acute myocardial infarction (AMI) cut-off for each assay. **Method**: Web of Science, SPORTDiscus, MEDLINE, ScienceDirect and Scopus databases were systematically searched up to November 2017. Studies were screened, quality-assessed and data was systematically extracted and analyzed. **Results**: From 751 studies initially identified, 14 met the inclusion criteria for data extraction. All three biomarkers were increased significantly after exercise. A decrease from post-exercise to 24 h was noted in cTnT and cTnI, although this decrease was only statistically significant for cTnT. The URL was exceeded by a 76% of participants for cTnT, a 51% for cTnI and a 13% for NT-proBNP. Furthermore, the cut-off value for AMI was exceeded by 39% for cTnT and a 11% for cTnI. Post exercise peak values of cTnT were associated with duration and intensity ($Q_{(3)}$ = 28.3, P < .001) while NT-proBNP peak values were associated with duration ($Q_{(2)}$ = 11.9, P = .003). **Conclusion**: Exercise results in the appearance of elevated levels of cTnT, cTnI and NT-proBNP in children and adolescents. Post-exercise elevations of cTnT and NT-proBNP are associated with exercise characteristics.

Background

Cardiac troponin T and I (cTnT and cTnI) are accepted indicators of myocyte necrosis and are considered sensitive markers of acute myocardial injury (MI) and infarction (AMI) (75). Serum cTnT and cTnI are elevated after irreversible heart muscle damage and levels peak during the subsequent days (1,60). The N-terminal fragment of the prohormone brain natriuretic peptide (NT-proBNP) is a marker accepted to reflect myocardial stretch (74), which is currently used to detect heart failure and asymptomatic left ventricular dysfunction (14,53) with the magnitude and duration of release dependent on the severity of stretch and stress (3).

The lower detection limits of cTnT and cTnI assays have been greatly reduced in recent years (59) with new high sensitivity assays available for both biomarkers. These assays can detect the 99^{th} percentile with a CV < 10% and measure cTn concentrations in at least a 50% of a healthy population at rest (59). Although the higher sensitivity of these assays enables better rates of true positive detection (40), a decline in specificity has been reported such that cTn appearance might be related to etiologies other than AMI (1,16,40). This can include physical exercise as a known non-pathological cause of cTn increase (1).

Numerous investigations have described the serological release of cTnT, cTnI and NT-proBNP after physical exercise and its kinetics (15,22,63). Contrary to an AMI-related release, cTn values normally peak within 2-5 h (cTnT) and 3-6 h (cTnI) post-exercise and then decrease returning to basal levels after 24 h of recovery in most participants (15,25). The differences between cTnT and cTnI peaks might be related to differences in their molecular weights (11). NT-proBNP release normally peaks immediately after exercise and remains elevated during the subsequent 72 h; and its clearance, that seems to take longer than cTn, has been related to a temporary reduction in kidney function subsequent to exercise (9,11). These observations have important clinical implications, since the elevation of these cardiac biomarkers for several hours after physical exercise might be misinterpreted in physically active patients, admitted to the emergency department for chest pain of origins other than acute coronary syndrome and heart failure.

The 99^{th} percentile of a normal reference population, considered the upper reference limit (URL), is designated as the decision level for the diagnosis of MI for both general and paediatrics populations (34,75). In this respect, the reported 99^{th} percentiles for children are lower than in adults for cTn and NT-proBNP (17,26,50), and both are used for clinical diagnostic (24). The magnitude of cTn and NT-proBNP post-exercise release, as well as the prevalence of data above clinical cut-offs have been extensively studied in healthy adults. Only a limited number of studies addressing the cardiac biomarker response to exercise in children and adolescents are currently available. Moreover, these studies are heterogeneous in terms of exercise exposure and often occur with small sample sizes and thus a limited statistical power. As a result, the association of cTn and NT-proBNP with exercise is currently controversial (7,29,44,52,61,65,67,69) and might be confounded with either individual as well as exercise characteristics.

Based on studies with adult participants other individual characteristics, other than age, might influence cardiac biomarkers release. Sex differences in cTn and NT-proBNP are controversial (4,6,10,23,30,36,56,80). Previous exercise experience has been negatively associated with cTn release (10,21,47,76) while training load might be not associated with biomarker appearance (18,21,28,33,68,79). NT-proBNP is not associated with previous exercise experience either (62,68,77) while its association with training load remains controversial (18,28,43,61,62,64,65,68). Finally, fitness condition has not been associated with cTn or NT-proBNP data (68,70). Exercise characteristics have also been studied as to their influence on cardiac biomarker release (15,71). Exercise intensity was mentioned as a predictor for cTn release while exercise duration has been correlated with both cTn and NT-proBNP data (8,9,12,64,68,83). Exercise mode and type have not been fully evaluated and any associations remain controversial (31,55,85).

Previous systematic reviews and meta-analyses related to cardiac biomarker release after exercise have been focused on adult participants (15,66,71,82). To the best our knowledge no systematic review or meta-analysis has been published addressing the cardiac biomarkers response to exercise in children and adolescents. Considering that children and adolescents have a low cardiovascular risk (2), we selected this special group in order to get a “clean” background and preclude the potential effects of concealed cardiovascular diseases and get "pure" effect of exercise on cardiac biomarkers. Due to variations in sample size and the diversity of participant and exercise characteristics a systematic review with a meta-analysis could contribute to the current knowledge by synthesizing available data into single, more powerful estimates of effect. Moreover, secondary analysis might help to identify possible associations with individual and exercise characteristics that could explain a certain degree of heterogeneity between the current findings.

In accordance with the PRISMA statement (41) the main objective of this study was to systematically review studies whose participants were healthy children and adolescents that were exposed to physical exercise and whose resting and post-exercise measures of cTnT, cTnI and NT-proBNP were described. A secondary objective was to analyse the moderator effects of a) age, b) pubertal status, c) sex, d) previous training (years), e) current training (h/week or km/week), f) exercise duration (minutes), g) exercise intensity (average HR), h) maximum oxygen uptake (VO_2max), and i) exercise mode on the pooled effects determined by the main objective.

Methods

Search strategy

We searched Web of Science, SPORTDiscus, MEDLINE, ScienceDirect and Scopus databases between July 1, 2017 and November 30, 2017. A three-component additive search key (*#A AND #B AND #C*) was used with: #A, measurement; #B, intervention; and #C, population. All searches were restricted to title or abstract, and keywords were stated in English. Measurement was defined with the expression *"cardiac biomarker*" OR Troponin OR TnT OR TnI OR cTn* OR hs-cTn* OR "N-terminal prohormone of brain natriuretic peptide" OR "NT-proBNP" OR "NT-pro-BNP"*. Intervention was specified with: *exercise OR sport* OR "physical activity" OR running OR marathon OR soccer OR swim* OR athletes*. Finally, population was stated with *"children OR adolescent* OR young"*.

Inclusion and exclusion criteria

We selected observational or experimental studies with a repeated measures design. Participants (or a subset of them) must be under the age of 18, not have personal history or clinical evidences of cardiovascular disease and have a normal 12-lead electrocardiogram and/or echocardiogram at rest (72). Interventions of interest were those which involved exposure to physical exercise, including sport events and laboratory tests. We searched primarily for studies that reported serum cardiac biomarkers responses to exercise. Specifically, those which reported cTnT and/or cTnI and/or NT-proBNP before and after exercise. Inclusion criteria included the necessity to report some quantitative measure of location and variation (mean with standard deviation (sd); median with range; or median with inter quartile range) of the biomarker's value for a minimum of one time point post-intervention. Studies where participants were exposed to specific pharmacological or nutritional interventions were excluded and the remaining articles were included in our review.

Data extraction

Studies were inspected to gather the data for (where available): sample size, sex, maturational status, age, training status (years of previous experience, weekly hours of training, weekly km of training), VO_2 max, performed exercise, exposure duration (minutes), average heart rate (surrogate of intensity) and absolute concentration of cTnT, cTnI or NT-proBNP before and after exercise. We also recorded the proportion of participants above the URL for each biomarker, and rate of participants above the cut-off for AMI for cTnT and cTnI. Outcomes reported as median [range] were transformed to mean (SD) using Wan et al.'s formulas (84). All concentrations were expressed in ng/L (75), and concentrations of cTn reported as "under limits of detection of 10 ng/L" were represented as 5 ng/L (12,48).

Quality assessment

We analysed the methodological quality of studies that met all inclusion criteria in order to detect possible methodological discrepancies that might explain a degree of heterogeneity between studies. In this sense, studies' quality was assessed by two authors independently, filling the Quality Assessment Tool for before-after (Pre-Post) studies with no control group from the National Heart Lung and Blood Institute (42). This scale considers 12 binary items, which average scores each article from 0 indicating *high risk of bias*, to 1 indicating *low risk of bias* (QAT_i). Discrepancies between assessors were resolved by a third author.

Statistical analysis

All analyses were performed in R (54) using Viechtbauer's "metafor" package (81). Random effects meta-analyses were conducted by biomarker (cTnT, cTnI and NT-proBNP) using the following estimates: the baseline concentration, the peak concentration, the concentration at 24 h, the absolute mean difference between baseline and peak concentrations, the absolute mean difference between baseline and concentration after 24 h recovery, the absolute mean difference between peak concentrations and concentrations at 24 h post exercise, the rate of participants whose peak concentration exceeded the assay URL and the rate of participants exceeding the cut-off for AMI. Rates were log-transformed for statistical comparisons and estimates were then back transformed for ease of interpretation. Heterogeneity was measured with Cochrane's Q statistic and I^2 values (19). We assessed publication bias using Egger's regression test for funnel plot asymmetry (5,57). Subgroup analyses were conducted when heterogeneity was significant to assess the possible influence of exercise mode, age, intensity and duration on the absolute mean difference between baseline and peak concentrations. In addition, when data was available, we investigated for the possible influence of Tanner stage, sex, VO_2max, years of previous training, weekly hours of training and weekly km of training, regardless of exercise mode, age, intensity and duration. Outcome multiplicity from the same groups (12) was controlled introducing a study identification as a random effect (51,81). Measures are expressed as mean ± 95% confidence intervals (CI) unless otherwise stated and we considered statistically significant differences when $P < .05$.

Results

The search process appears outlined in Figure 1. Fourteen studies met the inclusion/exclusion criteria that included 21 groups covering a total sample of 336 participants (72 females) who had a mean age of 15.1 ± 2.3 years (12,13,49,76–78,20,27,30,38,39,46–48). Two studies provided complete data from more than one subgroups contributing with different estimates by sex (27,78) or Tanner stage (30), which were treated as different units for the analysis. One study provided four outcome measurements from the same group at different exposures (12), which were controlled for multiplicity within the models (51,81). Interventions were based on five different modalities: in nine studies participants ran [three treadmill protocols (45 to 90 min) (13,46,77), five half marathons (12,27,47,48,76) and one full marathon (78)], in two studies basketball was employed (38,49), in one a soccer match (20), in one study participants swam for 60 min (30) and one included a set of table tennis exercises (39). Table 1 shows the number of groups available for each comparison (*k*) as well as their respective pooled effect sizes.

Figure 1

Figure 1. Flowchart for study inclusion and exclusion stages.

Table 1. Estimated pooled effect sizes (95% CI) by biomarker.

	K	Pooled Effect Size	Z	$p_{(Z)}$	Q	$p_{(Q)}$	I^2
Cardiac Troponin T							
Mean baseline (ng/L)	16	5 (4, 6)	11.84	< .001	206.47	< .001	98.7%
Mean peak (ng/L)	14	144 (83, 205)	4.65	< .001	105.78	<.001	96.5%
Mean at 24 h (ng/L)	9	11 (5, 16)	3.86	< .001	146.52	< .001	98.2%
Dif. Peak - Pre (ng/L)	14	139 (79, 198)	4.53	< .001	102.72	< .001	96.4%
Dif. 24 h - Peak (ng/L)	7	-89 (-147, -32)	-3.04	.002	33.85	< .001	93%
Dif. 24 h - Pre (ng/L)	9	7 (1, 12)	2.5	.01	87.22	< .001	96.3%
MI threshold IR	18	.76 (.66, .87)	-3.83	< .001	27.86	.047	13.5%
AMI threshold IR	14	.39 (.26, .6)	-4.38	< .001	39.1	< .001	75.4%
Cardiac Troponin I							
Mean baseline (ng/L)	7	16 (10, 22)	5.15	< .001	89.67	< .001	96.4%
Mean peak (ng/L)	5	248 (17, 478)	2.1	.04	61.42	< .001	99 %
Mean at 24 h (ng/L)	7	38 (19, 56)	4.05	< .001	348.01	< .001	97.7%
Dif. Peak - Pre (ng/L)	5	228 (6, 450)	2.01	.04	54.53	< .001	98.9%
Dif. 24 h - Peak (ng/L)	5	-199 (-404, 5)	-1.91	.06	42.56	< .001	98.2%
Dif. 24 h - Pre (ng/L)	7	21 (8, 33)	3.23	.001	100.97	< .001	93.2%
MI threshold IR	7	.51 (.32, .81)	-2.85	.004	16.74	.01	60.5%
AMI threshold IR	4	.11 (.05, .24)	-5.4	< .001	3.41	.33	24.4%
NT-proBNP							
Mean baseline (ng/L)	6	77 (14, 140)	2.38	.02	217.98	< .001	99.5%
Mean peak (ng/L)	6	106 (17, 195)	2.34	.02	288.19	< .001	99.5%
Mean at 24 h (ng/L)	4	83 (0*, 182)	1.63	.10	173.89	< .001	99.6%
Dif. Peak - Pre (ng/L)	6	20 (2, 38)	2.20	.03	13.64	.02	79.2%
Dif. 24 h - Peak (ng/L)	4	-2 (-11, 7)	-0.48	.63	7.26	.06	0.1%
Dif. 24 h - Pre (ng/L)	4	4 (-8, 28)	1.55	.44	0.65	.88	0%
MI threshold IR	6	.13 (.04, .44)	-3.32	< .001	18.02	.003	74.1%

Note: Estimated effects for Incidence Rates (IR) were back transformed for easier interpretation.

* Mathematically negative and truncated to 0 avoiding values outside the parameter space.

Quality assessment and risk of publication bias

Studies had a mean quality score of .61 (SD = .07). Pre-specification of sample eligibility criteria, enrollment of all eligible participants and sample size calculation were rated as *high risks of bias* in all studies. Other concurrent items rated as *high risk of bias* were blinding of outcome assessors, controlling for confounding variables in statistical analysis, reporting main effect of time with *p* values, and validity and reliability of outcome measures, in 12, 9, 3 and 1 cases, respectively. On the other hand, Egger's regression test was significant for all three biomarkers cTnT, cTnI and NT-proBNP ($P < .001$), suggesting that current literature was still unrepresentative of the population of completed studies.

Cardiac troponin T

Participants had an overall cTnT concentration at baseline of 5 ng/L (4 ng/L to 6 ng/L). This concentration was increased ($P < .001$) after 2-5 h, reaching a peak of 144 ng/L (83 ng/L to 205 ng/L). Finally, 24 h after exercise cTnT was reduced ($P < .002$) with a pooled concentration of 11 ng/L (5 ng/L to 16 ng/L), which was slightly higher than at baseline ($P = .01$) (Figure 2). All three pooled concentrations as well as their differences were heterogeneous between studies ($P < .001$ in all comparisons). Overall 76% (66% to 87%, $P < .001$) of participants had a cTnT peak above the assays URL, and a 39% (26% to 60%, $P < .001$) exceeded the cut-off for AMI. Again, both rates, for MI and for AMI, were heterogeneous between studies ($P = .047$ and $P < .001$, respectively).

In the subgroups analyses, cTnT was measured in four exercise modes, namely half marathon, treadmill running, table tennis and swimming. Exercise mode, available in $k = 14$ units with a total of n = 193 participants, had a main effect on cTnT increase-to-peak ($Q_{(3)}$ = 9.98, *P* = .02). Post-hoc analysis revealed that after a half marathon and treadmill run cTnT increases were higher than after intermittent table tennis and swimming (*P* < .001 and *P* = .004, respectively). Multiple regression with exercise mode as a random effect (*k* = 11, *n* = 138), revealed that age had a negative association (*P* < .001) while intensity and duration were positively associated (*P* < .001 and *P* = .003, respectively) with cTnT increase ($Q_{(3)}$ = 28.3, *P* < .001). Moreover, participants' VO_2max correlated negatively with cTnT increase (*k* = 7, *n* = 60, *P* = .04). We did not find associations between cTnT increase and sex (*k* = 11, *n* = 138, *P* = .3), Tanner stage (*k* = 4, *n* = 63, *P* = .5), years of previous training (*P* = .16) or weekly km of training (*k* = 10, *n* = 110, *P* = .32).

Figure 2

Figure 2. Estimated kinetics by biomarker before, at peak value and 24 h after exercise, with their respective 95% IC. Note: a = significant increase; b = significant decrease; c = higher than at baseline.

Cardiac troponin I

The pooled baseline concentration for cTnI was 16 ng/L (10 ng/L to 22 ng/L). After 3-6 h of exercise exposure participants increased this concentration (*P* = .04) up to a peak of 248 ng/L (17 ng/L to 478 ng/L). After 24 h recovery, this reduced to 38 ng/L (19 ng/L to 56 ng/L) which was not statistically different from the estimated peak concentration (*P* = .06) (Figure 2). However, all three pooled concentrations as well as their differences were heterogeneous between studies (*P* < .001 in all comparisons). The proportion of participants with cTnI above the URL was 51% (32% to 81%) and the rate exceeding the cut-off for AMI was 11% (5% to 24%). The rate for MI was heterogeneous (*P* = .01) while the rate for AMI was not (*P* = .33) between individual studies.

In the subgroup analysis, cTnI was measured in four exercise modes, namely half marathon, basketball, table tennis and soccer. The cTnI increase to peak did not differ between exercise modes (k = 5, n = 83, Q(4) = 4.75, P = .31), and did not either in a multiple comparison (k = 4, n = 61) at different ages (P = .33), intensities (P = .6) or durations (P = .31). In addition, we did not find differences due to years of training (k = 3, n = 33, P = .37) or participants' VO_2max (k = 3, n = 33, P = .54). Tanner stage and weekly training load data were not available to be modelled.

N-terminal prohormone Brain Natriuretic Peptide

The pooled baseline concentration for NT-proBNP corresponded to 77 ng/L (14 ng/L to 140 ng/L). This concentration was increased immediately after exercise (P = .03) achieving a peak of 106 ng/L (17 ng/L to 195 ng/L). Finally, 24 h after exercise NT-proBNP concentration did not differ from its peak (P = .63) or baseline (P = .44) with an estimate of 83 ng/L (0 ng/L to 182 ng/L) (Figure 2). All three concentrations were heterogeneous (P < .001). The rate of participants with NT-proBNP concentration above the URL was 13% (4% to 44%, P < .001), and studies were heterogeneous (P = .003).

In the subgroup analysis, NT-proBNP was present in four different exercise modes, namely half marathon, treadmill running, swimming and soccer. Exercise mode, had a main effect on the NT-proBNP post exercise increase (k = 6, n = 101, $Q_{(4)}$ = 25.06, P < .001). Post-hoc comparisons revealed that the higher NT-proBNP increases were related with soccer (estimated increase of 83 ng/L, 95%CI from 34 ng/L to 131 ng/L, P < .05) followed by half marathon (estimated increase of 59 ng/L, 95%CI from 12 ng/L to 105 ng/L, P = .01) and finally followed by swimming (estimated increase of 11 ng/L, 95%CI from 3 ng/L to 18 ng/L, P = .006), with no differences in the mode of treadmill running (P =.9). Moreover, in a multiple regression with exercise mode as a random effect (k = 4, n = 62), duration had a positive association with the estimate (P < .001) while age (P = .34) and intensity (P = .37) were not associated with NT-proBNP ($Q_{(2)}$ = 11.9, P = .003). Finally, we did not find differences in NT-proBNP for sex (k = 4, n = 62, P = .3), Tanner stage (k = 3, n = 50, P = .6) and years of previous training (k = 4, n = 62, P = .5). VO_2max, and weekly training load data were not available to be modelled.

Discussion

The main purpose of this systematic review and meta-analysis was to estimate how exercise modulated the blood concentration of cTnT, cTnI and NT-proBNP in children and adolescents. Overall, this review found: 1) all three biomarkers were significantly elevated after exercise; 2) a decrease from peak values after 24 h recovery was only significant for cTnT; 3) the rate of participants exceeding the biomarkers' URL were 76% for cTnT, 51% for cTnI and 13% for NT-proBNP; 4) the rate of participants exceeding the cut-off value for AMI were 39% for cTnT and 11% for cTnI; 5) individual variability was observed between studies; and 6) exercise duration influenced both cTnT and NT-proBNP while intensity influenced only cTnT. Despite these findings, the quality assessment of studies together with the analysis for publication bias revealed that current studies have a fair degree of quality with limited bias.

Cardiac troponin T and I

Our results indicate that cTn release in children and adolescents is inherent to physical exercise. Data reflect a fast increase of cTnT during the early hours of recovery, with close to complete recovery to baseline at 24 h. Similar results were appreciable for cTnI, although statistical power was limited and lead to only marginally significant differences between peak and 24 h values. Such observations suggest that cTn kinetics in children and adolescents during a 24 h recovery are comparable with the observed in adults (15,25). Our results coincide with previous research observing the highest cTnT and cTnI concentrations about 2-3 and 3-5 h post exercise, respectively (15,25). Based upon the foregoing, when repeated blood sampling are not possible, single samples taken within such interval might detect concentrations close to the kinetics peak.

The current data suggest that, as in the case of adults (31,33), there is a marked individual variability regarding the exercise induced release of cTn, with a high proportion of participants with values exceeding the URL for MI and AMI. As evidenced in controlled studies with adolescents (12) and adults (68), cTnT variability could be partially explained by exercise intensity and duration, what likely reflects an impact of exercise volume on cardiac work. We also observed a higher cTnT release in the younger participants, and this could explain that the proportion of participants exceeding the URL in our study is higher than the reported by a recent meta-analysis without age restrictions (66). This would suggest a role for maturity mediating the post exercise cTn release. However, direct comparisons of the release of cTn after exercise in adults and adolescents have disclosed contradictory findings (30,38,77). Moreover, with the scarce data currently available we did not find any association between cTnT release and pubertal status. At all events, associations with pubertal status require further investigation. Running seems to induce higher cTnT releases than other modes as it was noticed in a previous meta-analysis based on adult participants (71); nevertheless, such assertion is complex to verify through direct comparisons. Although we observed lower cTnT releases in participants with greater VO2max, we could not corroborate whether the cTnT increase is mediated by current training or training history. It was not evident whether there were any sex differences in the cTn release. This coincides with previous studies in adults which reported a limited influence of sex and training history on the release of cTn (4,27,30,32,33,38,78). The scarce number of studies did not allow to explain the between-subjects variability regarding the release of cTnI.

N-terminal prohormone Brain Natriuretic Peptide

An increase in NT-proBNP immediately after exercise was confirmed without a significant reduction within the 24 h recovery period that supports past research with adults (32,37). NT-proBNP may have a longer clearance period that cTn possibly extended to 72 h (9,11). In this regard, it has been suggested that BNP may play an important role in homeostasis during the transition of the circulation from children to maturity as a marker of myocardial growth (73). This might reflect an early myocardial adaptation to the intense training stimulus in children and adolescents. In either case, these possibilities require further study.

We noted that NT-proBNP changes with exercise were lower than the observed in cTn. Therefore, the proportion of participants exceeding the URL of NT-proBNP was lower than the reported in studies with adults (11,63). These differences might be associated with age. However, neither our analysis nor previous studies comparing directly adolescents with adults found NT-proBNP differences for age and pubertal status (30,77). It is therefore plausible to think that these differences might be related to exercises with less duration in studies conducted with adolescents compared with their equivalents with adults. Our results confirm indeed that in adolescents the release of NT-proBNP is largely associated with exercise duration, as it was reported previously in studies with adults (67,68). Given the close relationship between pre- and post-exercise values (32,33), baseline differences between studies might explain part of the differences we observed across NT-proBNP peak values depending on the exercise mode. Our results also confirmed that as in adults (4,30,32,33,67,68) exercise intensity, training, fitness and sex have limited influence on the release of NT-proBNP with exercise.

Clinical implications

A cardiac biomarker release was observed in most of the participants in all included studies, despite a certain degree of between-study variability. Importantly, this analysis shows that in children and adolescents, the factors mediating cardiac biomarkers after exercise as well as their kinetics, are comparable with the observed in previous studies in adults and differ from the observed after MI and AMI (74,75). It has been suggested that this reflects a reversible cellular process triggered by a normal physiological response to exercise (9,45,58,62). Likewise, the increase of cTn might reflect an increased rate and force of cardiac contraction during exercise that causes transient membrane damage and enables cystolic cTn to pass into circulation (69). On the other hand, a release of NT-proBNP from the ventricular cardiomyocytes might reflect a volume overload and cardiac wall stretch during exercise (11). Furthermore, some authors suggested that the use of the general population values as a reference might not be appropriate for adult athletes being evaluated for medical conditions using blood indices of cardiac biomarkers. This has prompted the reflection that cardiac biomarkers values might be stratified according to the physical activity of the adult subjects for improving the clinical usefulness of the biomarker (35). In this sense, our analysis extends this to children and adolescents, and suggests that when evaluating cTnT, cTnI and NT-proBNP in emergency settings, detailed information regarding any recent exercise should be obtained (38).

Limitations

The main limitation of this systematic review and meta-analysis derives from the incomplete data provided by a range of heterogeneous studies. Moderator analyses were performed with reduced numbers that decreased statistical power. This lack of statistical power might explain some non-significant results such as the inconclusive decrease in cTnI within a 24 h post-exercise recovery. We did not incorporate assay precision to our meta-analysis which could have explained certain degree of the study-to-study heterogeneity (71). Finally, we found differences between studies regarding when peak concentrations were taken or noted. In conclusion, more research should be conducted with children and adolescents analyzing such covariate parameters.

Conclusion

In conclusion, cardiac biomarkers in children and adolescents are significantly increased form rest to post-exercise with the URL exceeded by a 76% of participants for cTnT, a 51% for cTnI and a 13% for NT-proBNP and the cut-off value for AMI exceeded by 39% for cTnT and a 11% for cTnI. Finally, we confirmed that the cTnT release is mainly associated with exercise duration and intensity, while the NT-proBNP release remains influenced only by exercise duration.

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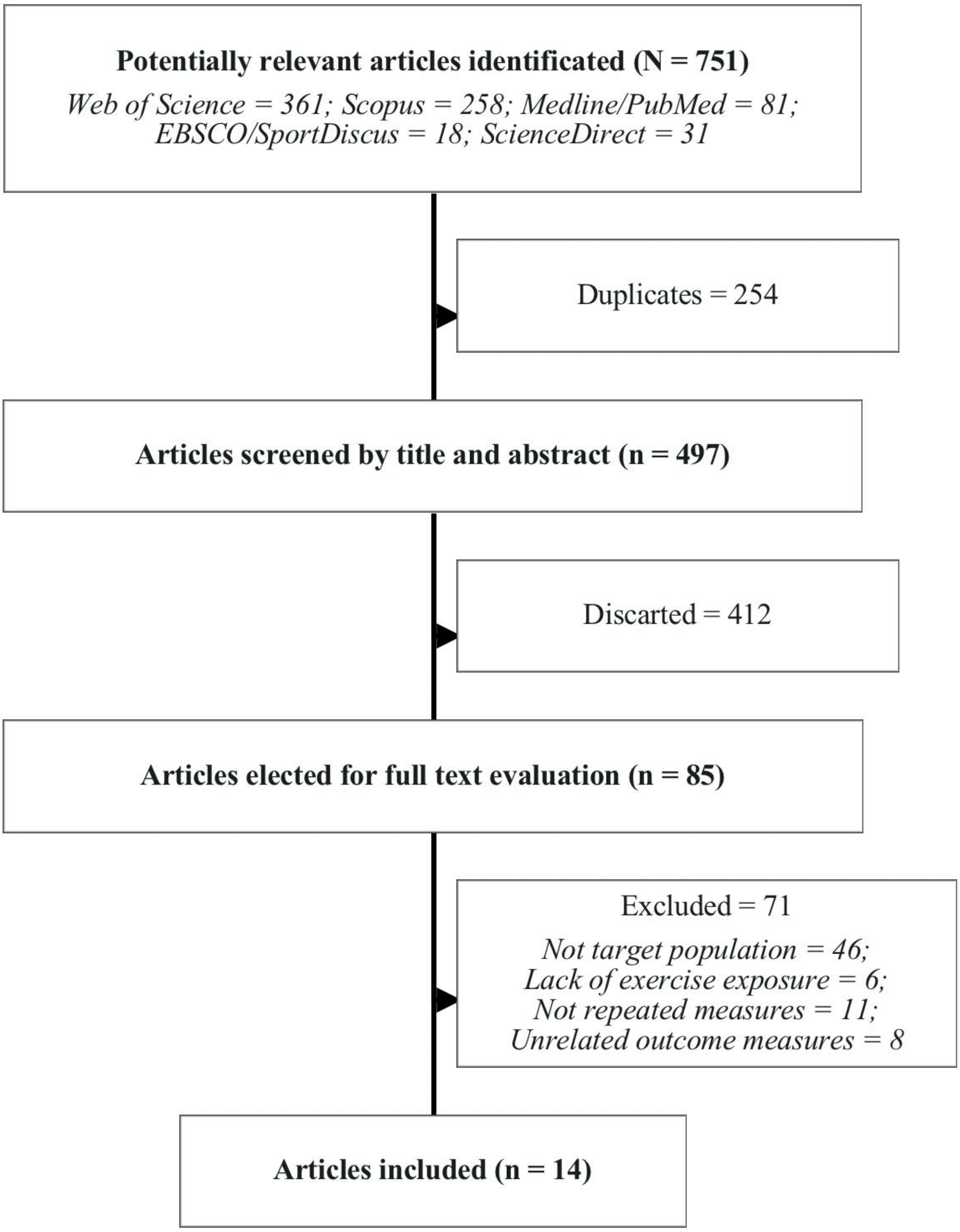
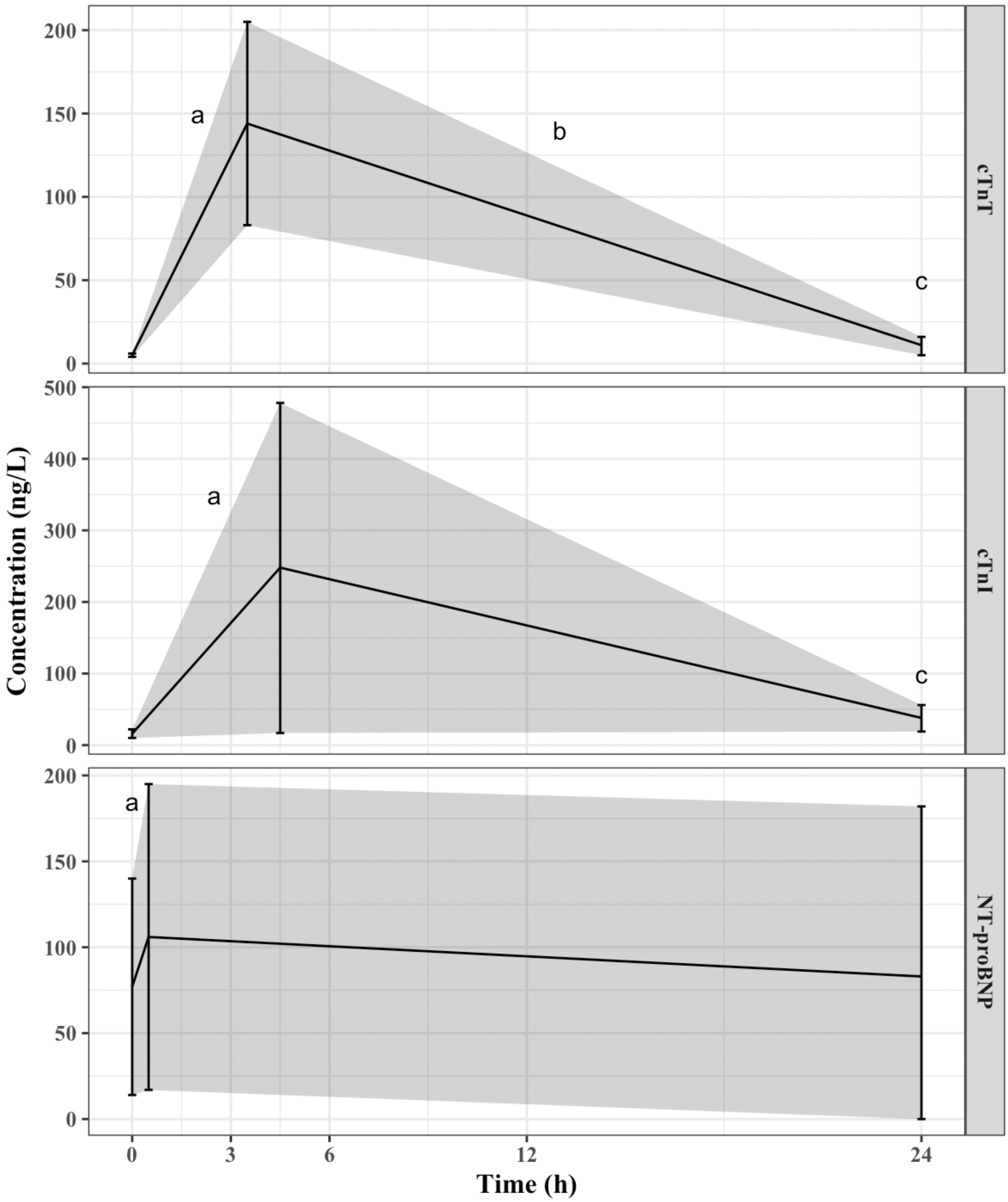

Potentially relevant articles identificated (N = 751)
Web of Science = 361; Scopus = 258; Medline/PubMed = 81; EBSCO/SportDiscus = 18; ScienceDirect = 31
Duplicates = 254
Articles screened by title and abstract (n = 497)
Discarted = 412
Articles elected for full text evaluation (n = 85)
Excluded = 71
Not target population = 46; Lack of exercise exposure = 6; Not repeated measures = 11; Unrelated outcome measures = 8
Articles included (n = 14)



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