

Palatability and Voluntary Intake of Three Commercially Available Sports Drinks and Unflavored Water during Prolonged Exercise in Hot and Humid Conditions

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Investigators

Anita M. Rivera-Brown¹, Luis F. Aragón-Vargas, FACSM², Yazaira Cabrera-Dávila¹, Luis E. Berríos¹.

¹Center for Sports Health and Exercise Sciences, Physical Medicine, Rehabilitation and Sports Medicine, University of Puerto Rico School of Medicine, San Juan, PR. ²Gatorade Sports Science Institute, San José, Costa Rica.

Introduction

Studies using laboratory exercise protocols have demonstrated that palatability and sensory characteristics of beverages may affect drink intake during exercise (Passe et al., 2004) and recovery (Wilmore et al., 1997). Subjective perceptions such as stomach fullness or heat, or beliefs such as the importance of hydration or the association between drinking and the occurrence of side stitch have not been shown to be as strongly associated with voluntary fluid intake (Solera-Herrera and Aragón-Vargas, 2006). Sex-related differences in drinking patterns during prolonged exercise have also been documented (Baker et al., 2005; Hew, 2005).

Passe et al. (2004) examined the palatability and fluid intake of 4 beverages: Diluted orange juice, homemade 6% carbohydrate-electrolyte sports beverage, commercially available 6% carbohydrate-electrolyte sports beverage and water in a group of triathletes and runners. They were given brief access to the beverages for 1 minute after 30 min and 60 min of exercise. Results showed that the commercial sports drink scored higher in overall acceptance and was consumed in greater quantities. Wilmore et al. (1997) found that during recovery following a 90 minute run at 60% VO₂max subjects consumed approximately 50% more fluid when drinking two sports drinks compared with water. Passe et al. (1997) have also shown that the presence of sodium benzoate in a beverage affects fluid intake. Sodium benzoate is a preservative commonly used in carbonated drinks.

Sex-related differences in drinking pattern of marathon runners (Hew, 2005) and older adults (Baker et al., 2005) have been reported. In these studies women drank more water than men in proportion to body size. In addition, Baker et al. (2005) reported that older women rate the “overall acceptance” and the “liking of flavor” of water higher than men.

The present study was designed to simulate training situations in natural outdoor conditions in which athletes have unlimited access over a long period of time to water or beverages that have different palatability and sensory characteristics (flavor, carbohydrate, electrolytes, vitamins, preservatives). Our goal was to compare the voluntary intake of four beverages in male and female athletes who tend to minimize drinking (runners and race walkers), during prolonged exercise outdoors in a hot and humid climate.

Purpose

This research study compared the palatability and voluntary intake of four beverages which are commercially available in male and female athletes during prolonged exercise in a warm and humid environment. The beverages vary in carbohydrate and electrolyte composition and preservative content.

Methodology

Subjects

Thirty-six athletes (runners n=31; racewalkers n=5), 18 males (mean age=18.9 ± 3.5 yr) and 18 females (mean age=20.1 ± 4.7 yr) completed the study. Nine of each group were adolescents and 9 were adults.

Procedures

Measurements before exercise

Upon arrival we obtained a urine sample in a plastic container and determined its volume, color and specific gravity as indices of hydration status. Subjects were weighed nude using a scale accurate to 20g.

Measurements during exercise

Subjects completed four 90-minute exercise sessions, running or race walking outdoors at an intensity requiring 80 to 85% of age predicted maximum heart rate in a hot and humid environment (mean WBGT=30.1 ± 1.1°C) on separate days in the summer months of August and September. They were instructed to run laps around a marked

area of 420 meters for six-15 minute intervals. Subjects wore a heart rate monitor and at the completion of each lap they were asked to report the heart rate to assure they were maintaining the exercise intensity required. In addition, heart rates were stored every 15 seconds and downloaded to a computer program for subsequent calculation of average heart rate sustained during the exercise intervals. We also counted the laps completed in each 15 minute interval to calculate total distance covered. Environmental conditions were measured every 15 minutes using a WBGT heat stress monitor.



Exercise Area

One of four commercial beverages was offered on each experimental session: unflavored water (W), a 6% carbohydrate-electrolyte solution (CES), a 6% carbohydrate-electrolyte + preservatives solution (CESP1); and an 8% carbohydrate-electrolyte + preservatives + B vitamins solution (CESP2).

Composition of commercial beverages offered in the four experimental conditions (per 100mL)

Beverage	CHO (g)	Na+ (mg)	K+ (mg)	Preservatives	Vitamins	Osmolality (mOsm/L)
Water	0	0	0	None	None	0
CES	6	46	12.5	None	None	325-380
CESP1	6	46	12.5	Sodium Hexametaphosphate	None	325-380
CESP2	8	31	21	Potassium Sorbate Sodium Benzoate (<0.06%)	B12 (0.25 µg) B3 (0.75 mg) B6 (0.10 mg)	381

Drink flavors for CES, CESP1, and CESP2: Orange or Fruit Punch

Beverage order was assigned in a Latin Square, double-blind design. Beverages were served cold ($\approx 9^{\circ}\text{C}$) in labeled squeeze bottles and subjects drank as desired during the entire exercise session. Bottles were kept in a cooler with ice while the subjects ran or race walked. Palatability was measured pre-exercise and during a one-minute exercise break at each 15-minute interval using visual analog 10-point scales and 9-point category scales.



Bottles kept in cooler



Palatability Measurements

Taste and Sensory Measurements (Palatability)

- Overall Acceptance, liking of flavor and liking of sweetness were measured using 9 point hedonic category scales.
- Perceived intensity of thirst, sweetness, saltiness, tartness, thirst quenching, palatability and flavor strength were measured using visual analog 10-point scales. We also used this scale to rate the question “Can you drink a lot of this beverage?”.
- Perception of exercise difficulty and how hot/overheated subjects felt were measured using a visual analog 10-point scale.

Measurements after exercise

At the end of the exercise session we obtained a urine sample in a plastic container and determined its volume, color and specific gravity as indices of hydration status. Subjects were weighed nude using a scale accurate to 20g.

Statistical Analysis

A Student's t-test was used to compare subjects' characteristics between sexes. A one-way analysis of variance (ANOVA) was used to compare variables related to body fluid balance and indices of hydration status between conditions. A two-way ANOVA (condition vs. sex) was used to compare males and females in body fluid balance and indices of hydration status and in variables measured throughout time such as taste and sensory variables. A three-way (condition vs time vs sex) repeated measures ANOVA was performed where appropriate. The Tukey post hoc test was performed when main effects were found. Significance level for all statistical tests were set to $\alpha=0.05$. Data are presented as means \pm SD.

Results

Subjects

- Males were taller than females and had a higher body weight and surface area.
- The subjects had been training for an average of 5 to 6 years, 6 days per week, 2 to 3 hours per day.

Descriptive characteristics of the subjects

	Males	Females	Total
Number of subjects	18	18	36
Age (yr)	18.9 ± 3.5	20.1 ± 4.7	19.5 ± 4.1
Weight (kg)	60.1 ± 8.7*	52.8 ± 3.6	56.4 ± 7.6
Height (cm)	172.5 ± 7.5*	161.7 ± 4.2	167.1 ± 8.1
Surface area (m ²)	1.72 ± 0.1*	1.55 ± 0.1	1.63 ± 0.1
Years training	4.8 ± 1.8	5.9 ± 3.9	5.3 ± 3.1
Days/week training	5.9 ± 0.4*	5.5 ± 1.0	5.7 ± 0.8
Hours/day training	2.9 ± 0.5*	2.2 ± 0.7	2.6 ± 0.7

Values are means ± SD.

*Higher than females, P < 0.05.

Environmental Conditions

- The average climatic conditions were hot (31.5 ± 2.0 °C) and humid (67.1 ± 6.2 % RH).
- There were no differences between conditions (P > 0.05) in climatic conditions.

Environmental Conditions (whole group x condition)

	Unflavored Water	CES	CESP1	CESP2	Total
Wet bulb temperature (°C)	26.5 ± 0.5	26.4 ± 0.6	26.5 ± 0.7	26.5 ± 0.5	26.5 ± 0.6
Dry bulb temperature (°C)	31.5 ± 2.1	31.2 ± 2.2	31.5 ± 1.4	31.6 ± 2.2	31.5 ± 2.0
Globe temperature (°C)	42.2 ± 3.5	41.5 ± 4.1	41.4 ± 4.2	42.4 ± 3.9	41.9 ± 3.9
WBGT Index (°C)	30.1 ± 0.9	29.9 ± 1.2	30.0 ± 1.3	30.2 ± 1.1	30.1 ± 1.1
Relative Humidity (%)	66.7 ± 5.8	67.6 ± 6.8	67.9 ± 5.9	66.2 ± 6.7	67.1 ± 6.2

No differences between conditions in environmental variables, $P > 0.05$.

Prevalent Environmental Conditions (males versus females x condition)

	Unflavored Water		CES		CESP1		CESP2	
	M	F	M	F	M	F	M	F
Wet bulb temperature (°C)	26.5 ± 0.4	26.5 ± 0.5	26.3 ± 0.3	26.4 ± 0.8	26.3 ± 0.7	26.6 ± 0.7	26.4 ± 0.5	26.6 ± 0.5
Dry bulb temperature (°C)	32.0 ± 1.4	30.9 ± 2.6	31.8 ± 1.2	30.7 ± 2.9	31.6 ± 1.5	31.5 ± 1.3	31.5 ± 3.0	31.7 ± 1.1
Globe temperature (°C)	41.9 ± 3.7	42.6 ± 3.3	41.6 ± 3.0	41.4 ± 5.0	40.9 ± 4.6	42.0 ± 3.7	42.0 ± 4.5	42.9 ± 3.1
WBGT Index (°C)	30.1 ± 1.0	30.2 ± 0.8	29.9 ± 0.7	29.9 ± 1.5	29.8 ± 1.4	30.2 ± 1.2	30.1 ± 1.3	30.4 ± 0.9
Relative Humidity (%)	65.5 ± 6.5	67.9 ± 4.8	65.7 ± 5.3	69.4 ± 7.6	67.0 ± 5.5	68.8 ± 6.2	64.9 ± 7.3	67.6 ± 5.9

No differences between *males and females in environmental variables in any condition*, $P > 0.05$.

Exercise intensity and distance

- There were no differences between conditions ($P > 0.05$) in average heart rate and % maximal heart rate during the exercise session. Males covered more distance (18.0 ± 1.7 km) than females (13.1 ± 2.0 km) in all conditions ($P < 0.05$).

Exercise intensity and distance (whole group x condition)

	Unflavored Water	CES	CESP1	CESP2
Heart rate (beats•min ⁻¹)	163.3 ± 5.0	163.9 ± 5.9	163.8 ± 5.9	163.7 ± 7.0
% Maximal heart rate	81.8 ± 2.4	82.0 ± 2.9	81.9 ± 3.0	81.9 ± 3.3
Distance covered (km)	15.6 ± 3.2	15.5 ± 3.2	15.6 ± 3.1	15.5 ± 3.1

No difference between conditions, $P > 0.05$.

Exercise Intensity and distance (males versus females x condition)

	Unflavored Water		CES		CESP1		CESP2	
	M	F	M	F	M	F	M	F
Heart rate (beats•min ⁻¹)	164.2 ± 5.6	162.4 ± 4.3	165.4 ± 5.9	162.4 ± 5.8	164.9 ± 4.9	162.7 ± 6.7	164.3 ± 7.2	163.2 ± 6.9
% Maximal heart rate	82.0 ± 2.4	81.6 ± 2.4	82.5 ± 2.7	81.6 ± 3.1	82.2 ± 2.4	81.7 ± 3.6	82.0 ± 3.2	81.9 ± 3.3
Distance covered (km)	18.1 ± 1.9*	13.0 ± 2.1	18.1 ± 1.8*	12.9 ± 2.0	18.1 ± 1.6*	13.2 ± 2.1	17.9 ± 1.8*	13.1 ± 2.1

* Significant difference between males and females in distance covered in all conditions, $P < 0.05$.

Indices of Hydration Status

- Subjects arrived to the exercise sessions in an adequate state of hydration as indicated by the urine specific gravity (W=1.020 ± 0.007; CES=1.021 ± 0.007; CESP1=1.020 ± 0.009; CESP2=1.021 ± 0.007 g/ml). No differences were found between conditions in any of the hydration indexes, P > 0.05.

Indices of hydration status (whole group x condition)

	Unflavored Water	CES	CESP1	CESP2
Urine Color Pre (1 - 8)	3.9 ± 1.4	3.9 ± 1.2	3.9 ± 1.7	4.0 ± 1.6
Urine Color Post (1 - 8)	5.3 ± 1.2	5.3 ± 1.5	5.2 ± 1.6	5.4 ± 1.4
Δ Urine Color	-1.5 ± 1.3	-1.4 ± 1.2	-1.4 ± 1.3	-1.3 ± 1.2
Specific Gravity Pre (g•ml ⁻¹)	1.020 ± 0.007	1.021 ± 0.007	1.020 ± 0.009	1.021 ± 0.007
Specific Gravity Post (g•ml ⁻¹)	1.022 ± 0.006	1.022 ± 0.006	1.023 ± 0.007	1.023 ± 0.007
Δ Specific Gravity	-0.002 ± 0.005	-0.002 ± 0.004	-0.002 ± 0.003	-0.007 ± 0.004

No differences between conditions, P > 0.05.

Indices of hydration status (females versus males x condition)

	Unflavored Water		CES		CESP1		CESP2	
	M	F	M	F	M	F	M	F
Urine Color Pre (1 - 8)	3.8 ± 1.5	3.9 ± 1.4	3.8 ± 1.2	4.0 ± 1.1	4.1 ± 1.8	3.8 ± 1.6	4.1 ± 1.6	3.9 ± 1.5
Urine Color Post (1 - 8)	5.4 ± 1.2	5.2 ± 1.2	5.1 ± 1.5	5.5 ± 1.5	5.3 ± 1.5	5.1 ± 1.6	5.5 ± 1.4	5.3 ± 1.5
Δ Urine Color	-1.7 ± 1.5	-1.3 ± 1.0	-1.3 ± 1.0	-1.6 ± 1.4	-1.4 ± 1.5	-1.5 ± 1.1	-1.2 ± 1.4	-1.3 ± 0.9
Specific Gravity Pre (g•ml ⁻¹)	1.021 ± 0.007	1.020 ± 0.007	1.021 ± 0.007	1.020 ± 0.007	1.019 ± 0.008	1.020 ± 0.009	1.021 ± 0.007	1.022 ± 0.007
Specific Gravity Post (g•ml ⁻¹)	1.023 ± 0.005	1.020 ± 0.006	1.022 ± 0.006	1.022 ± 0.006	1.022 ± 0.006	1.022 ± 0.008	1.024 ± 0.007	1.022 ± 0.007
Δ Specific Gravity	-0.002 ± 0.004	-0.001 ± 0.006	-0.002 ± 0.003	-0.002 ± 0.004	-0.002 ± 0.004	-0.002 ± 0.004	-0.002 ± 0.004	0.0005 ± 0.003

No differences between males and females in any condition, P > 0.05.

Body Fluid Balance

- The amounts consumed of the four beverages were similar and insufficient to match sweat rates ($W=17.0 \pm 4.8$; $CES=16.9 \pm 5.4$; $CESP1=17.8 \pm 5.4$; $CESP2=17.5 \pm 5.2$ $\text{ml}\cdot\text{kg}^{-1}$, $P > 0.05$).

Body Fluid Balance (whole group x condition)

	Unflavored Water	CES	CESP1	CESP2
Body weight pre (kg)	56.3 ± 7.6	56.4 ± 7.6	56.3 ± 7.6	56.6 ± 7.9
Body weight post (kg)	55.1 ± 7.1	55.2 ± 7.1	55.1 ± 7.1	55.4 ± 7.5
Δ in body weight (kg)	1.2 ± 0.6	1.2 ± 0.7	1.2 ± 0.6	1.2 ± 0.6
Fluid intake ($\text{ml}\cdot\text{kg}^{-1}$)	17.0 ± 4.8	16.9 ± 5.4	17.8 ± 5.4	17.5 ± 5.3
Sweat loss ($\text{ml}\cdot\text{kg}^{-1}$)	37.2 ± 8.7	37.1 ± 9.0	36.9 ± 8.9	37.6 ± 8.8
Sweat rate ($\text{L}\cdot\text{h}^{-1}$)	1.41 ± 0.45	1.42 ± 0.47	1.41 ± 0.48	1.44 ± 0.48
Fluid loss ($\text{ml}\cdot\text{kg}^{-1}$)	38.3 ± 8.7	38.0 ± 9.0	38.0 ± 9.2	38.5 ± 8.7
Dehydration (% BW)	2.1 ± 1.0	2.1 ± 1.0	2.0 ± 0.9	2.1 ± 0.9
Rehydration (%)	46.9 ± 17.2	47.1 ± 18.7	48.9 ± 16.6	47.1 ± 16.9

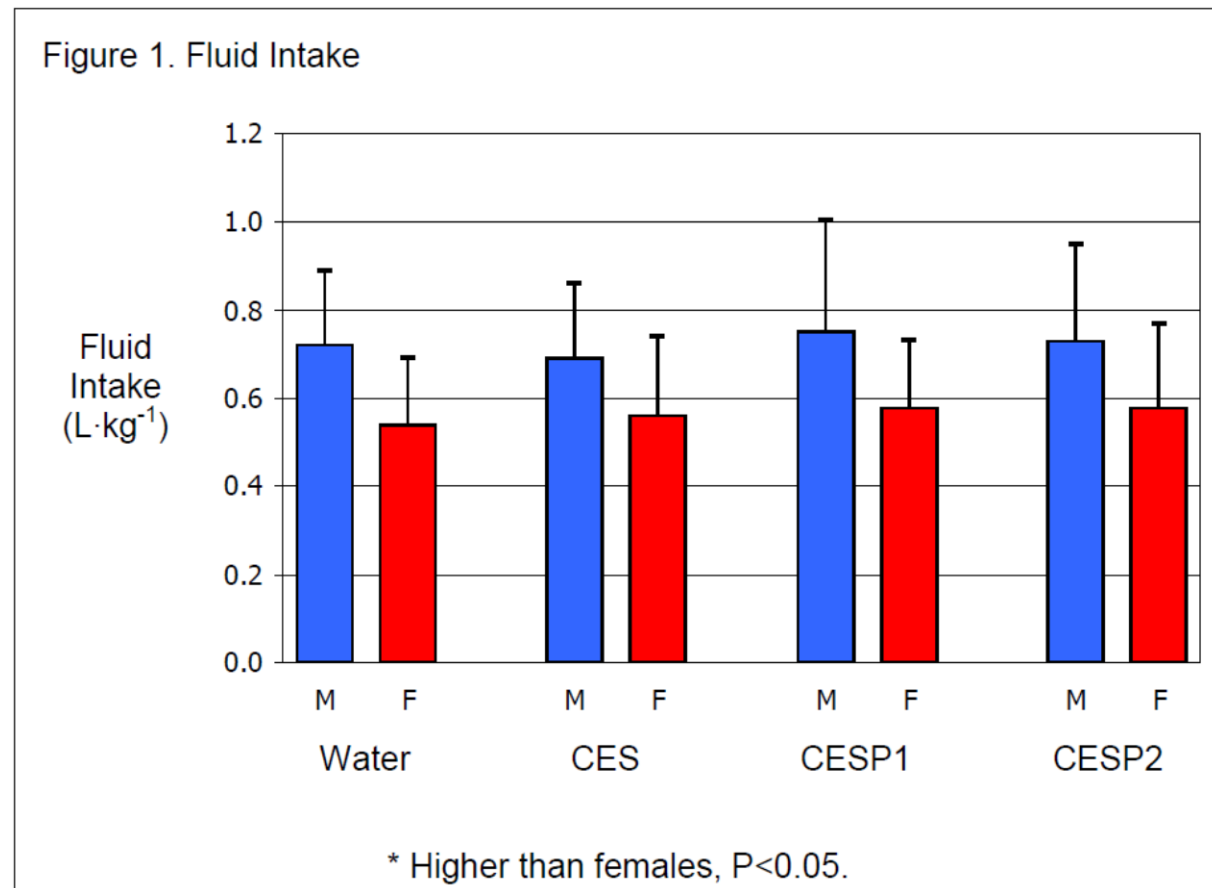
No significant differences between conditions, $P > 0.05$.

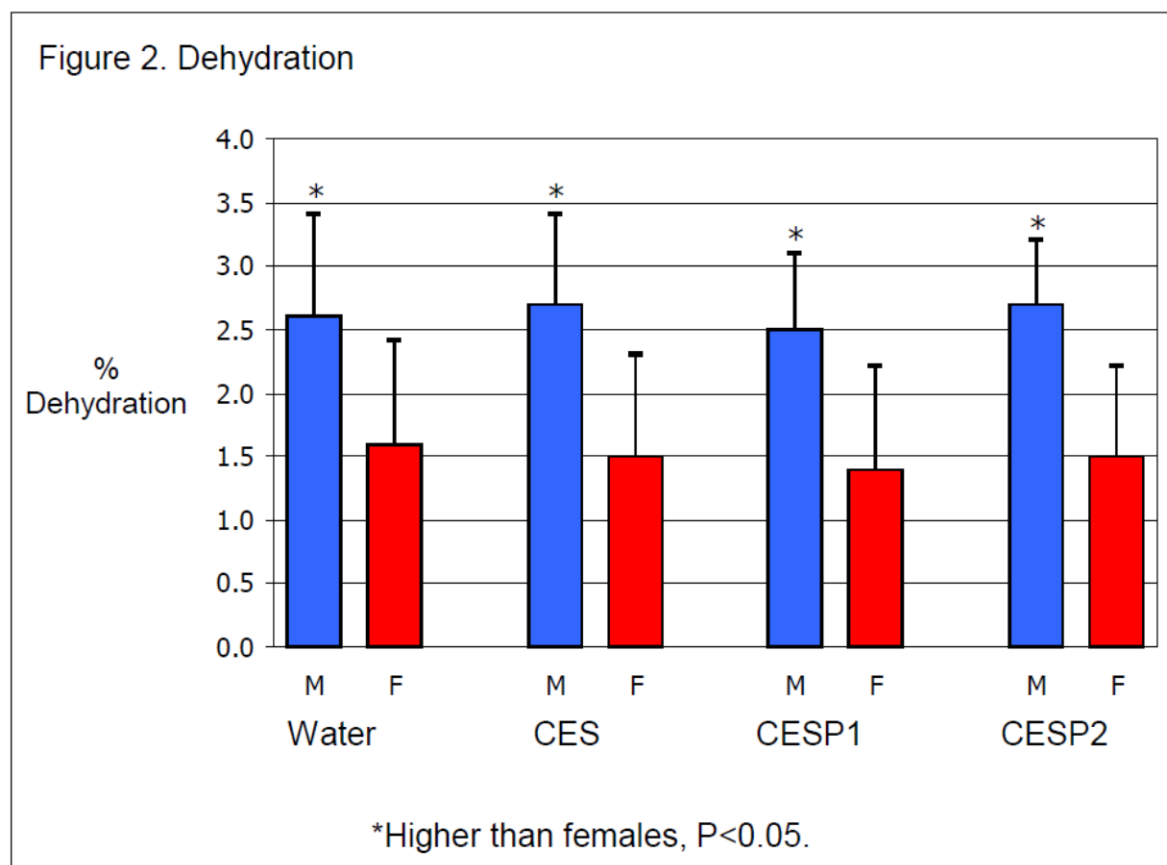
- Males showed a higher fluid intake (18.5 ± 5.4 vs. 16.1 ± 4.7 $\text{ml}\cdot\text{kg}^{-1}$, $P=0.006$) but greater level of dehydration (2.6 ± 0.7 vs. 1.5 ± 0.8 % BM) in all conditions ($P < 0.001$).

Body Fluid Balance (females versus males x condition)

	Unflavored Water		CES		CESP1		CESP2	
	M	F	M	F	M	F	M	F
Body weight pre (kg)*	59.8 ± 8.9	52.8 ± 3.6	60.1 ± 8.8	52.7 ± 3.6	59.8 ± 8.9	52.8 ± 3.7	60.6 ± 9.0	52.7 ± 3.7
Body weight post (kg)*	58.2 ± 8.4	52.0 ± 3.6	58.4 ± 8.3	52.0 ± 3.6	58.2 ± 8.4	52.0 ± 3.6	58.9 ± 8.6	51.9 ± 3.7
Δ in body weight (kg)*	1.6 ± 0.6	0.8 ± 0.4	1.7 ± 0.6	0.8 ± 0.4	1.6 ± 0.6	0.8 ± 0.4	1.7 ± 0.5	0.8 ± 0.4
Fluid intake (ml•kg ⁻¹)	18.6 ± 4.8	15.5 ± 4.3	17.8 ± 5.4	16.0 ± 5.3	19.1 ± 6.3	16.6 ± 4.2	18.5 ± 5.4	16.5 ± 5.1
Sweat loss (ml•kg ⁻¹)*	44.0 ± 5.4	30.4 ± 5.2	44.3 ± 4.8	30.0 ± 5.8	43.6 ± 6.0	30.2 ± 5.6	44.7 ± 5.0	30.5 ± 5.0
Sweat rate (L•h ⁻¹)*	1.8 ± 0.4	1.1 ± 0.2	1.8 ± 0.3	1.0 ± 0.2	1.7 ± 0.4	1.1 ± 0.2	1.8 ± 0.4	1.1 ± 0.2
Fluid loss (ml•kg ⁻¹)*	45.1 ± 5.6	31.4 ± 5.1	45.1 ± 4.8	30.9 ± 6.1	44.8 ± 6.4	31.3 ± 6.1	45.6 ± 4.8	31.4 ± 5.1
Dehydration (% BW)*	2.6 ± 0.8	1.6 ± 0.8	2.7 ± 0.7	1.5 ± 0.8	2.5 ± 0.6	1.4 ± 0.8	1.5 ± 0.7	2.7 ± 0.5
Rehydration (%)*	42.3 ± 14.4	51.5 ± 19.5	39.9 ± 12.7	54.2 ± 21.3	42.5 ± 12.2	55.4 ± 18.1	40.4 ± 10.9	53.8 ± 19.3

* Significant difference between males and females in all conditions, P < 0.05.





Taste and Sensory Measurements

Comparison of Conditions

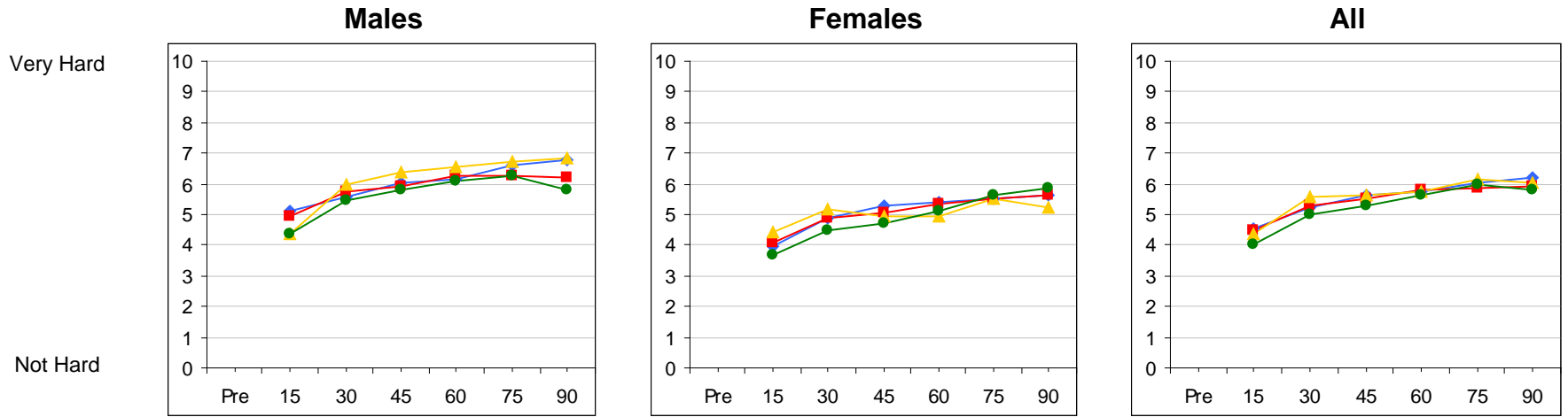
- No differences were found between conditions for ratings of perceived difficulty of exercise, how hot/overheated the subjects felt, thirst intensity, or in ratings of “can you drink a lot of this beverage?”
- No differences were found between conditions for ratings of palatability, thirst quenching, liking of flavor, liking of sweetness or overall acceptance.
- Males and females rated the sweetness, saltiness, tartness, and flavor strength of water lower than the other three conditions.

Comparison of males versus females

- No differences were found between males and females in ratings of difficulty of exercise in any of the conditions.
- No differences were found between conditions or between males and females for ratings of overall acceptance, liking of flavor, thirst quenching, palatability, flavor strength, or in ratings of “can you drink a lot of this beverage” in any of the conditions.

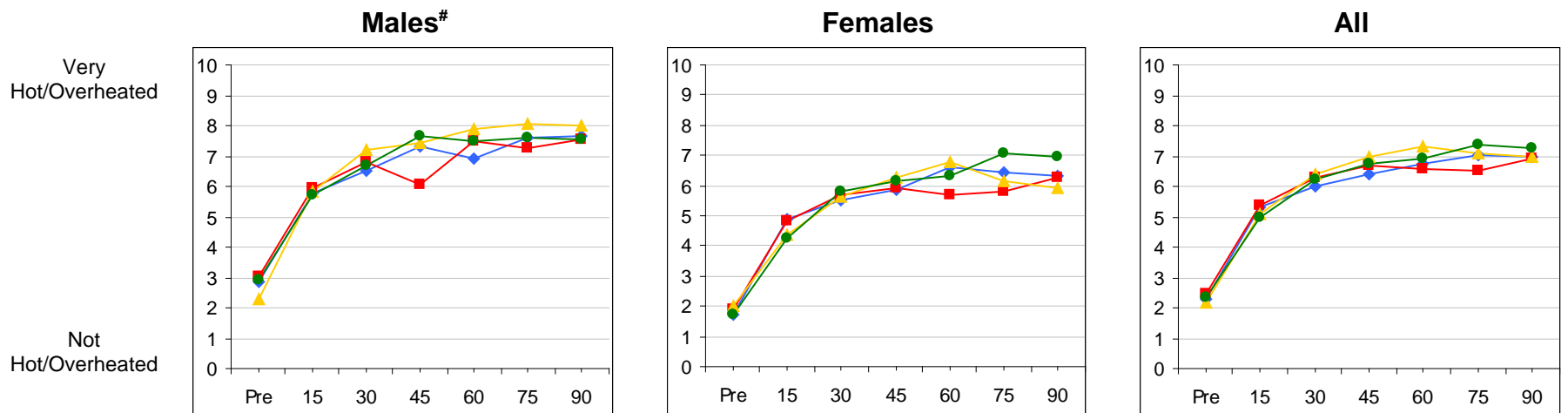
- Males rated the perception of hot/overheated higher than females in the CESP1 (min 15, 30, 45, 75, 90) conditions.
- Males rated the sweetness of the beverage (pre-exercise, 30, 60, and 90 min) higher than females in the CESP1 condition.
- No differences were found between males and females for ratings of saltiness, tartness and sweetness in any of the conditions.
- Males rated thirst intensity higher than females in the CES (all time points) and CESP1 (min 30, 45, 60, 75, and 90).

Perceived Difficulty of Exercise



No difference between conditions, $P > 0.05$; No difference between males and females, $P > 0.05$.

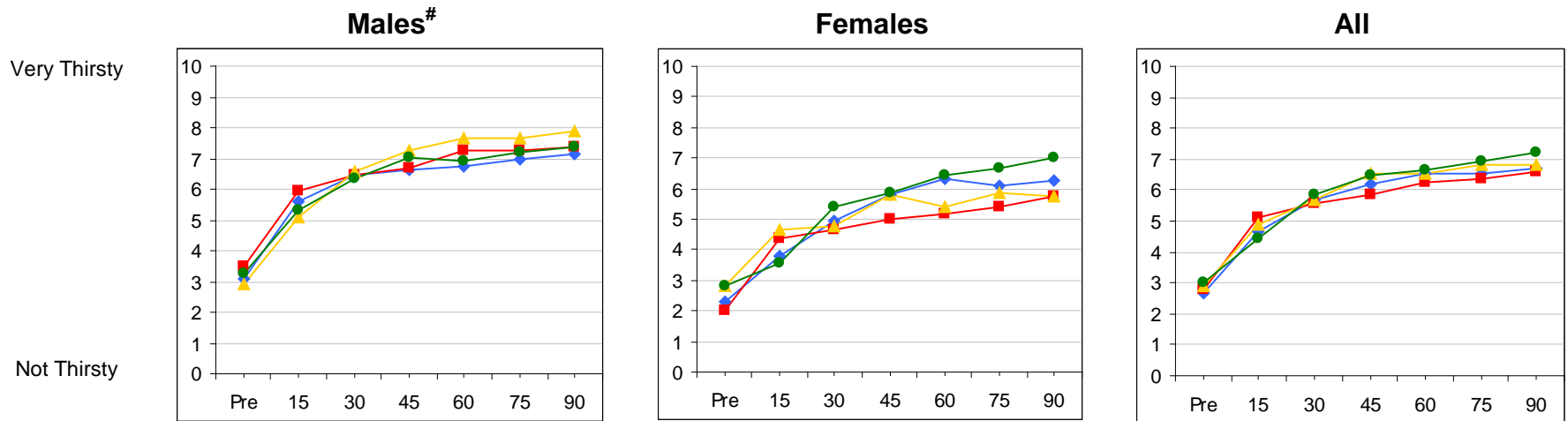
Hot / Overheated



No difference between conditions, $P > 0.05$; # $P < 0.05$ males vs females for CES and CESP1.

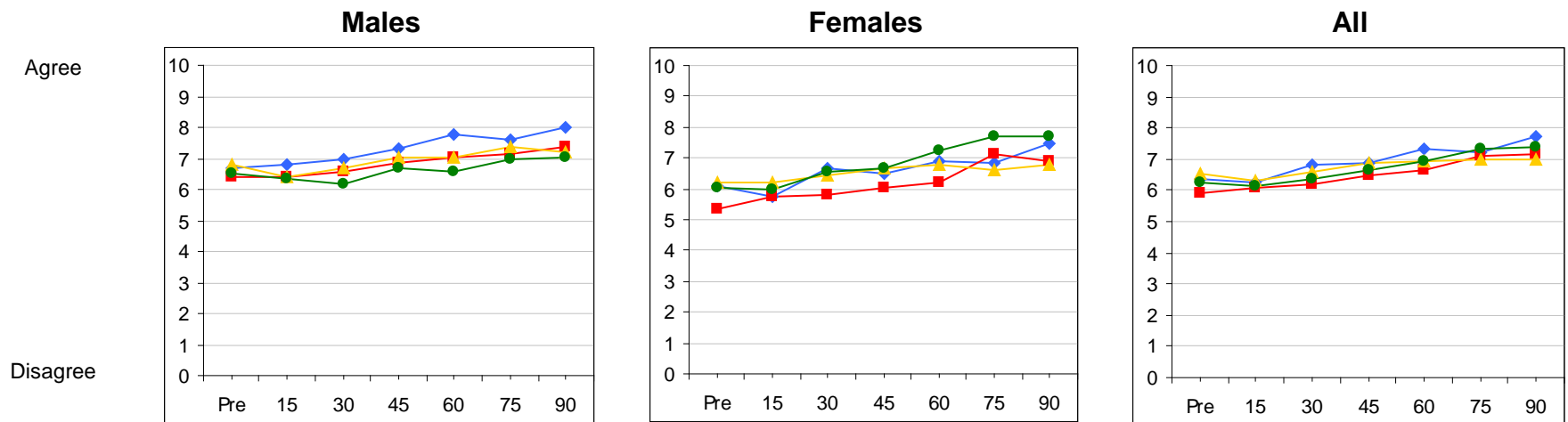


Thirst Intensity



No difference between conditions, $P > 0.05$; # $P < 0.05$ males vs females for CES and CESP1.

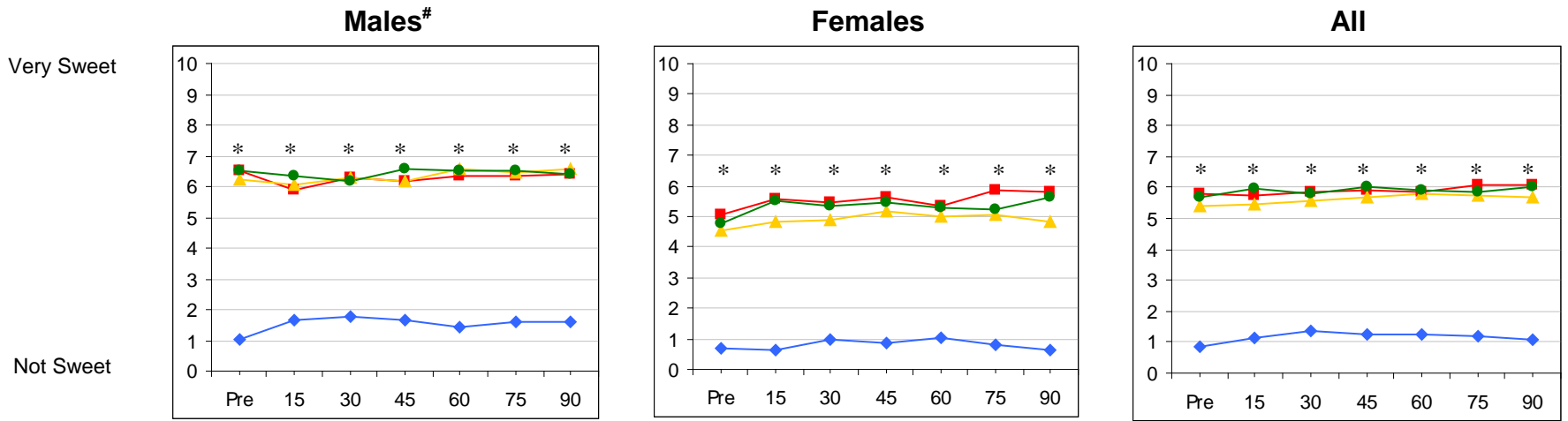
Can you drink a lot of this beverage?



No difference between conditions, $P > 0.05$; No difference between males and females, $P > 0.05$.

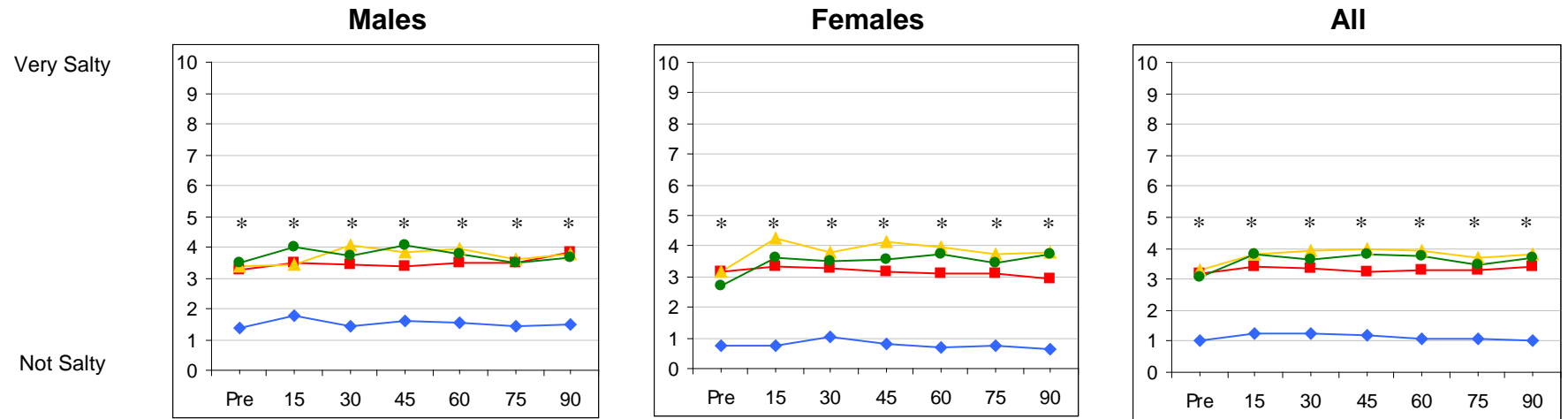


Sweetness



* P < 0.05 water vs other three conditions; # P < 0.05 males vs females for CESP1.

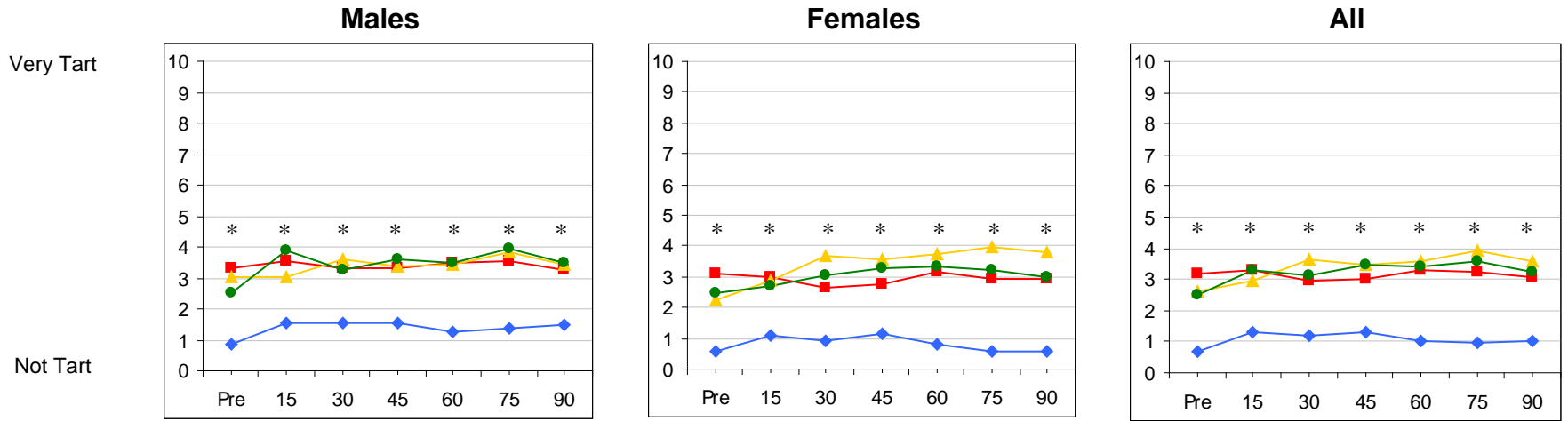
Saltiness



* P < 0.05 water vs other three conditions; No difference between males and females, P > 0.05.

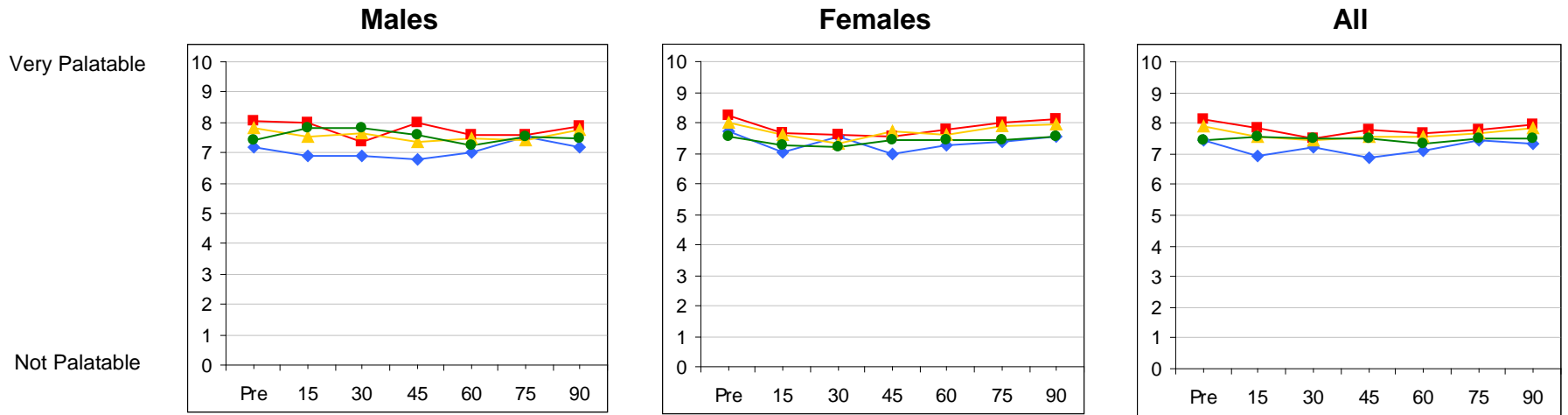


Tartness



* P < 0.05 water vs other three conditions; No difference between males and females, P > 0.05.

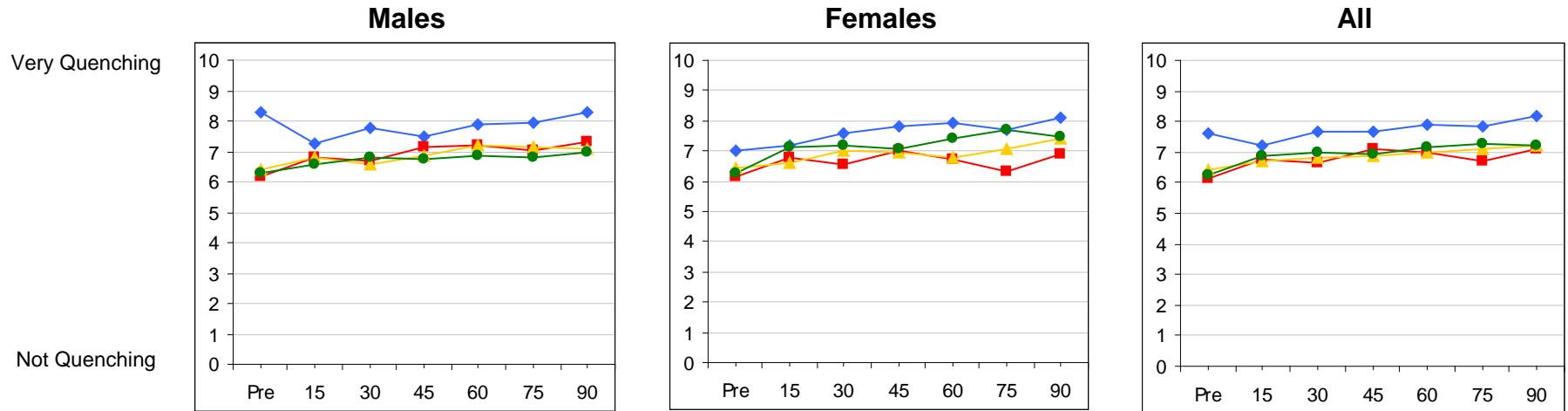
Palatability



No difference between conditions, P > 0.05; No difference between males and females, P > 0.05.

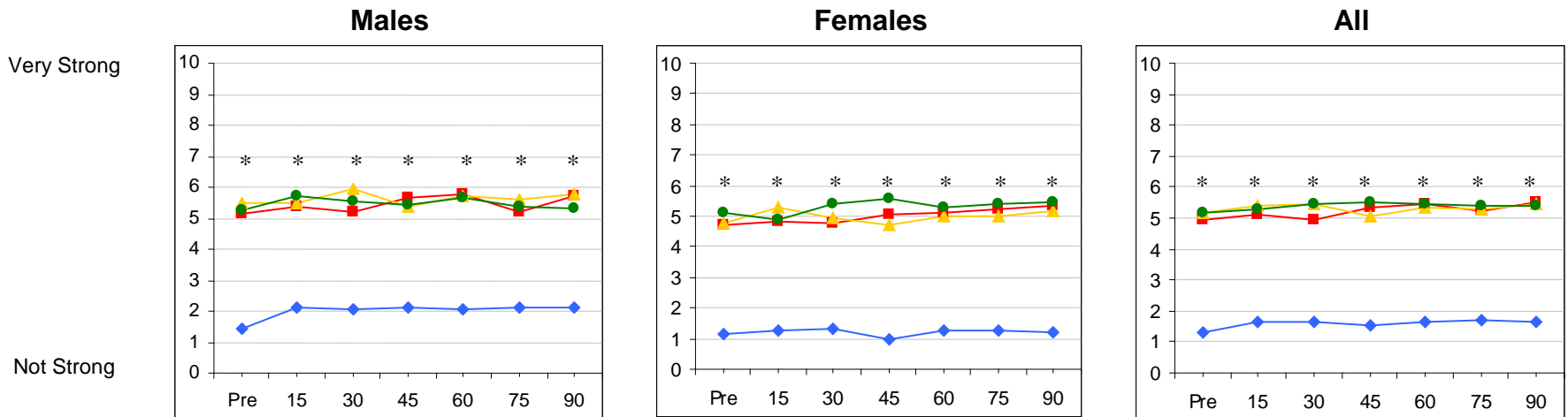


Thirst Quenching



No difference between conditions, $P > 0.05$; No difference between males and females, $P > 0.05$.

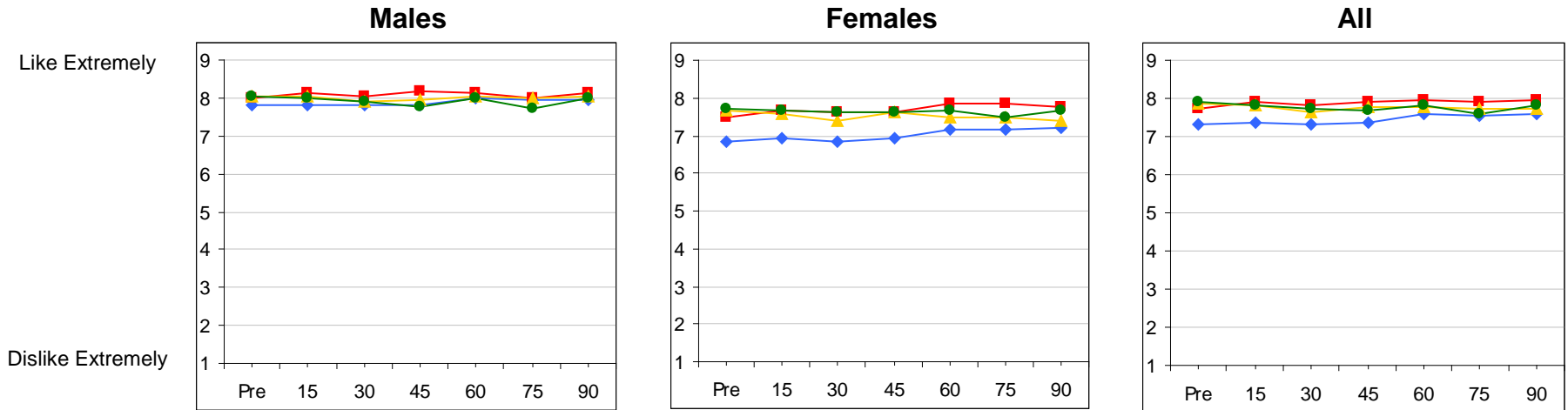
Flavor Strength



* $P < 0.05$ water vs other three conditions; No difference between males and females, $P > 0.05$.

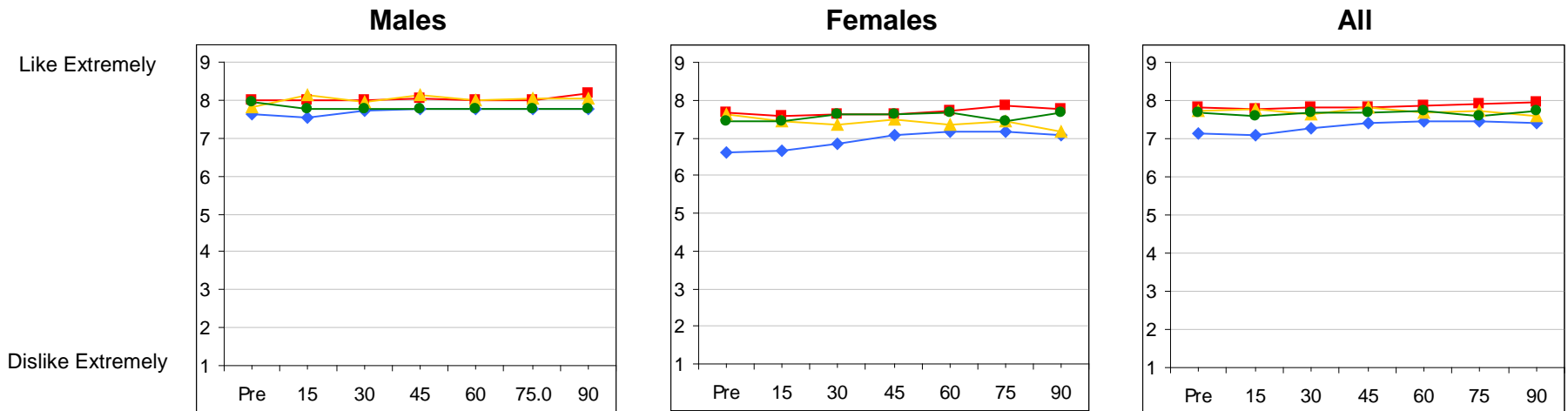


Liking of Flavor



No difference between conditions, $P > 0.05$; No difference between males and females, $P > 0.05$.

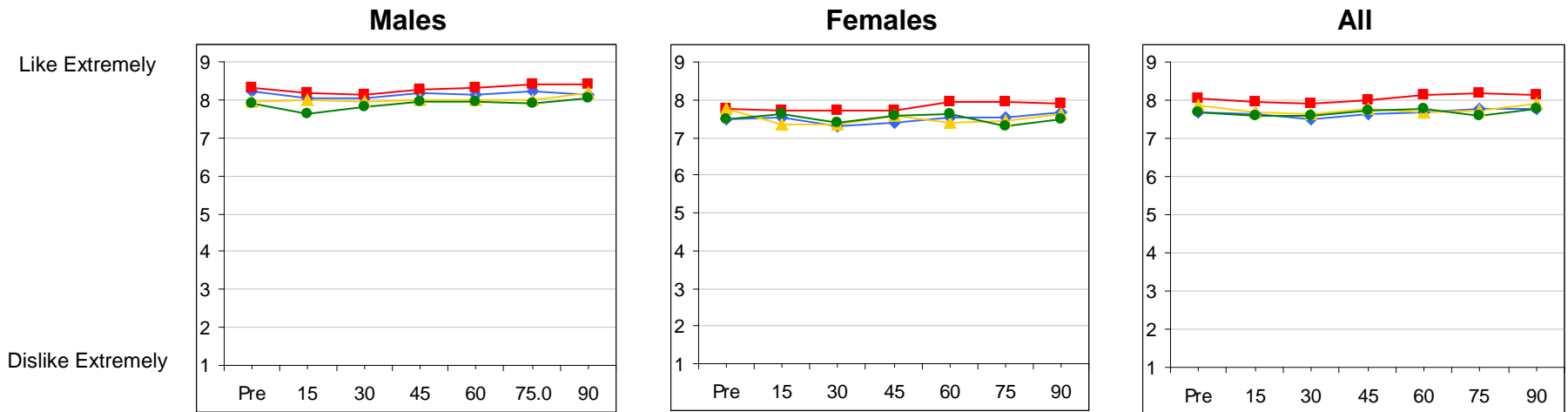
Liking of Sweetness



No difference between conditions, $P > 0.05$; No difference between males and females, $P > 0.05$.



Overall Acceptance



No difference between conditions, $P > 0.05$.



Conclusions

In this study of 36 male and female young athletes, running or race-walking for 90 minutes in outdoor heat (WBGT=30.1±1.1°C), at an intensity requiring 80 to 85% of age-predicted maximum heart rate:

- Female athletes replaced more of their sweat losses than males but both groups finished dehydrated (males = 2.6 ± 0.7 vs. females = 1.5 ± 0.8 % BM), with no differences among beverages.
- Contrary to a previous report in older individuals, females did not drink more water than males.
- The presence or absence of artificial preservatives made no difference in terms of palatability or voluntary fluid intake.
- The reluctance of young athletes to drink while running or racewalking in a hot and humid outdoor environment (overall mean fluid intake = 17.3 ± 5.2 mL/kg, for a voluntary dehydration = 2.1 ± 0.1%) did not seem to be due to the palatability of these beverages and should be further investigated.

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