Nutrición Hospitalaria

Nutr Hosp. 2013;28(6):1815-1819
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Revisión

Validation of beverage intake methods *vs.* hydration biomarker; a short review

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Abstract

Introduction: **Fluid intake is difficult to monitor. Biomarkers of beverage intake are able to assess dietary intake / hydration status without the bias of self-reported dietary intake errors and also the intra-individual variability. Various markers have been proposed to assess hydration, however, to date; there is a lack of universally accepted biomarker that reflects changes of hydration status in response to changes in beverage intake.**

Aim: **We conduct a review to find out the questionnaires of beverage intake available in the scientific literature to assess beverage intake and hydration status and their validation against hydration biomarkers.**

Methods: **A scientific literature search was conducted. Only two articles were selected, in which, two different beverage intake questionnaires designed to capture the usual beverage intake were validated against Urine Specific Gravidity biomarker (Usg).**

Results: **Water balance questionnaire (WBQ) reported no correlations in the first study and the Beverage Intake Questionnaire (BEVQ), a quantitative Food frequency questionnaire (FFQ) in the second study, also found a negative correlation. FFQ appears to measure better beverage intake than WBQ when compared with biomarkers. However, the WBQ seems to be a more complete method to evaluate the hydration balance of a given population.**

Conclusions: **Further research is needed to understand the meaning of the different correlations between intake estimates and biomarkers of hydration in distinct population groups and environments.**

(*Nutr Hosp.* 2013;28:1815-1819)

DOI:10.3305/nh.2013.28.6.6886

Key words: *Water. Beverages intake. Hydration biomarkers.*

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Recibido: 11-VI-2013.
1.ª Revisión: 7-VIII-2013
Aceptado: 20-VIII-2013.

VALIDACIÓN DE MÉTODOS DE INGESTA DE BEBIDAS FRENTE A BIOMARCADORES DE HIDRATACIÓN; PEQUEÑA REVISIÓN

Resumen

Introducción: **La ingesta de líquidos es difícil de monitorear. Los biomarcadores de ingesta de bebidas son capaces de evaluar la ingesta dietética / estado de hidratación sin el sesgo producido por los errores de los autoregistros de ingesta dietaria, así como por la variabilidad intra-individual. Se han propuesto diversos marcadores para evaluar el estado de hidratación; sin embargo, hasta la fecha, no existe ningún biomarcador universalmente aceptado que refleje los cambios del estado de hidratación en respuesta a cambios en la ingesta de bebidas.**

Objetivo: **Hemos llevado a cabo una revisión para determinar los cuestionarios de ingesta de bebidas disponibles en la literatura científica que evalúan la ingesta de bebidas y el estado de hidratación y que han sido validados con biomarcadores de hidratación.**

Métodos: **Se realizó una búsqueda bibliográfica en la literatura científica. Se seleccionaron sólo dos artículos, los cuales contenían dos cuestionarios de ingesta de bebidas diferentes, diseñados para capturar la ingesta habitual de bebidas. Ambos cuestionarios fueron validados con el biomarcador Gravedad específica de la orina (Usg).**

Resultados: **El Cuestionario de Balance Hídrico (WBQ) no reportó correlaciones en el primer estudio y el Cuestionario de Ingesta de Bebidas (BEVQ), que es un cuestionario de frecuencia de consumo alimentario (FFQ) en el segundo estudio, tampoco encontró una correlación positiva. El FFQ parece medir mejor la ingesta de bebidas que el WBQ en comparación con los biomarcadores. Sin embargo, el WBQ parece ser un método más completo para evaluar el balance hídrico de una población dada.**

Conclusión: **Se necesita más investigación para entender el significado de las diferentes correlaciones entre las estimaciones de ingesta y los biomarcadores de hidratación en distintos grupos de población y en diferentes entornos.**

(*Nutr Hosp.* 2013;28:1815-1819)

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Palabras clave: *Agua. Consumo de bebidas. Biomarcadores de hidratación.*

Introduction

Interest in the type and quantity of beverage consumption is not new, and numerous approaches have been used to assess beverage intake, but the validity of these approaches has not been well established. Some research objectives have focused on assessment of beverage-associated nutrients or intakes of individual beverages (eg, caffeine was investigated in Kennedy et al. 1991 study[1], milk drinking in Mettlin 1989 study[2] or alcoholic beverages) was evaluated in a Serra-Majem et al. 2002 survey[3]. Other investigators have extrapolated beverage intakes from previously collected diet records or diet questionnaire[4-6]. In most of the studies, food frequency questionnaires (FFQ), multiple-day food records and 24-hour dietary recalls have been used successfully to estimate beverage intake. However, although several beverage intake questionnaires have been developed during the past decade[7-10]; the available questionnaires were designed to measure beverage intake in children and adolescents, and most do not exclusively measure beverage intake (eg, Neuhouser et al. 2009 questionnaire assessed beverage and snack intake)[11].

It is well know that fluid intake is difficult to monitor. A common limitation of research in this area is a reliance on self-reported measures of habitual intake[12]. Thus, the need for novel methods to intake objectively assess beverage intake, such as beverage's biomarkers, has been recognized[13-15]. Biomarkers of intake are able to objectively assess dietary intake/ status without the bias of self-reported dietary intake errors[13-15], and also overcome the problem of intra-individual diet variability[16].

Dietary biomarkers are not exempt of limitations; cost and degree of invasiveness are factors to be taken into account[12]. Therefore, the need for non-invasive, inexpensive and specific dietary markers is clear[13]. In addition, some dietary intake methods use biomarkers to validate the data that being collected. However, there is a surprising paucity of studies that systematically examine the correlation of beverages intake and hydration biomarker in different populations.

Various markers have been proposed to assess the state of hydration (plasma osmolality, urine specific gravity (USG), urine osmolality), which can be used in different laboratory conditions, clinical practice or sports (Table I). However, to current date, there is lack of a universally accepted biomarker that reflects of the increase hydration status in response to an increase beverage intake. Therefore, there are no markers defined as "gold standard"[17,18].

Aim

We conduct a review to find out the questionnaires of beverage intake available in the scientific literature to assess beverage intake and hydration status and their validation against hydration biomarkers.

Table I
Characteristics of hydration biomarkers[23]

Hydration assesment technique	*Body fluids involved*
Stable isotope dilution	All (ECF and ICF)
Neutron activation analysis	All
Bioelectrical impedance spectroscopy (BIS)	Uncertain
Body mass change[a]	All
Plasma osmolality[b]	ECF
% plasma volume change	Blood
Urine osmolality	Excreted urine
Urine specific gravity	Excreted urine
Urine conductivity	Excreted urine
Urine colour	Excreted urine
24-hour urine volume	Excreted urine
Salivary flow rate, osmolality, total protein	Whole, mixed saliva
Rating of thirst	Hypothalamus

BIS: Bioelectrical impedance spectroscopy; ECF: Extracellular fluid; ICF: Intracellular fluid.
[a]Using a floor scale.
[b]Freezing point depression method.

Materials and Methods

The literature search was conducted in Medline, using the following terms: *"beverage", "drinking water", "drinking", "nutrition assessment", "diet", "questionnaires", "osmolar concentration", "urinalysis", "body water", "biological marker"* including MESH-terms. In total 229 articles were selected.

The following exclusion criteria were applied: (a) studies conducted exclusively in diseased individuals, (b) studies of diseases related to beverage intake, (c) studies in animals, (d) studies written in languages other than English or Spanish, (f) studies which used non validated assessment method, (g) studies that do not include adults in the study population and (h) studies using another dietary method different from FFQ as a reference tool.

A total of 42 articles appeared to be potentially relevant, and we attempted to obtain them in full-text version. The literature lists in the selected papers were checked. Only 12 articles were chosen because included hydration biomarkers outcomes, but only two of them could be selected to evaluate the correlation between beverage intake methods estimates against biomarkers of hydration status. Details of the two papers selected are given in Table II.

In the articles included in the review, two different beverage intake questionnaires were validated: Water balance questionnaire (WBQ) in Malisova et al. 2012 study[19] and a Beverage Intake Questionnaire (BEVQ) in Hedrick et al. 2010 study[20].

The WBQ included a series of questions regarding a) the profile of the individual; b) consumption of solid

Table II
Correlation for beverage intake questionnaire vs. biomarker

Author	*Country*	*n (subjects)*	*Dietary method which was validated*	*Biomarker*	*Results*
Malisova et al.[19]	Greece	40	WBQ: 3 day diary: 2,264 ± 789 ml/day	Urine indices	Urine volume *(Uvol)* (ml/24h): r = 0.29, p= 0.015 Urine Color (Ucol): r = -0.28, p = 0.033 **Urine Specific Gravity *(Usg)*: r = -0.107, p = 0.403** PH: r = -0.093, p = 0.483 Women: *(Uvol)* (ml/24h): r = 0.3, p = 0.04 (n = 25) *(Ucol)*: r = -0.35, p = 0.033 *(Uosm)*(mOsm/kg): r = 0.43, p = 0.004 Men (n = 15) = all ps > 0.05
Hedrick et al.[20]	USA	105: 45 men; 60 women	BEVQ (FFQ) Time 1: 2,017 ± 94 g BEVQ (FFQ) Time 2: 1,965 ± 96 g	Urine indices	**Urine Specific Gravity *(Usg)*: r = -0.202, p < 0.05** **Urine Specific Gravity *(Usg)*: r = -0.238, p < 0.05**

WBQ: Water balance Questionnaire; BEVQ: Beverage intake Questionnaire; FFQ: Food Frequency Questionnaire; r: Spearman Correlation.

and fluid food (FFQ which included 58 food items); c) drinking water or beverage intake; d) physical activity; e) sweating; f) urine and faecal excretions and g) trends on fluid and water intake, and it was filled in a 3-day diary.

The BEVQ was evaluated in two occasions (BEVQ1, BEVQ2). It included 19 categories of beverages plus one open-ended section for "other" beverages not listed. This tool is a quantitative FFQ; the frequency of food items consumed and amounts consumed were also assessed.

Both questionnaires were designed to capture the usual beverage intake.

The numbers of participants varied from 40 healthy volunteers (15 men and 25 women) in Malisova study[19] of 105 (45 men and 60 women) in Hedrick study[20]. The age distribution ranged from 22 to 57 years in the first study and 39 ± 2 years, with mean ages from 29 to 49 years in the second.

Both questionnaires were validated against Urine Specific Gravity (*Usg*) as a biomarker. However, in Malisova study[19], urine volume, urine color, urine osmolality and pH also were considered as gold standard biomarkers. Spearman's p coefficient was calculated.

Results

Daily beverage intakes and correlations between intakes estimated from the beverages questionnaires and hydration biomarkers are reported in table II.

Malisova study[19] reported no correlations between beverage intake estimated from the WBQ against Urine Specific Gravity ranging of -0.107, $p = 0.403$. However, they found moderated correlations with the others biomarkers measured.

Moreover, results reveled high validity of the WBQ among females (n = 25; correlation with urine osmolality $r = 0.43$, $p = 0.004$; with urine volume $r = 0.3$, $p = 0.04$ and with urine colour $r = -0.35$, $p = 0.033$) but not among males (n = 15; all *ps* > 0.05).

Hedrick study[20] found a correlation measured by FFQ (BEVQ) which was also negatively at time 1 and 2 (-0.202, $p < 0.05$ was found in the first measure, when people drank 2,017 ± 94 g and -0.238, $p < 0.05$ in the second measure when people drank 1,965 ± 96 g).

Discussion

In our review, the FFQ (of the Hedrick' study) appears to be better measuring method for assessed (of the Malisova' study) beverage intake than the 3-day dietary questionnaire when compared with biomarkers. However, this conclusion is based just in the global correlations found from FFQ and Urine Specific Gravity of two papers. There not gold method or gold biomarker. Thus the WBQ of the Malisova et al. study seems to a more complete method to evaluate the hydration balance.

It is clear that the development of properly validated BFQ may improve the evidence behind hydration outcomes.

Information regarding water balance in various population groups is limited. One reason may be that the methodology available for the direct measurement of water intake and loss is rather complicated and therefore not easily applicable in a large number of volunteers. A practical research tool that could facilitate gathering data may be a questionnaire that thoroughly evaluates water intake and loss. Several questionnaires have been developed to evaluate water intake or the contribution of solid and fluid foods to water intake. These are usually based on reporting the recalled frequency of intake of fluid and solid foods and of drinking water. Despite errors linked to recalling or to estimating the portions of intake, these questionnaires were able to record relatively accurately water intake as shown by validation procedures. However, there is little information on questionnaires that evaluate both intake and loss of water, and thus evaluate water balance[19].

In a validation study, the reference method used should be as accurate as possible[21]. A validation study is also called a relative validation/calibration study when one dietary method is compared to another beverage method, most often BFQ vs. several days of beverage records. The correlation coefficients obtained from the validation studies can reflect the capability of the method to rank individuals according to beverage intake. However, the limitations with this approach are the considerable individual day-to-day variation, which reduces the possibility of obtaining a true measure of usual intake with few recording days, as well as reporting bias since beverage assessment questionnaires and beverage records are based on self-reporting[21]. Other limitation with beverage records is that subjects are prone to underestimate their beverage intake when they keep food records[22].

In our review, women display higher correlations between theirs questionnaires and different measure biomarkers than men. This clearly suggests that women remember and refer more accurately food and beverage compsumitions than men.

Nevertheless, biomarkers were more accurate than different dietary methods to rank individuals. Although many hydration indices have been proposed, the gold standard for assessing hydration status remains elusive[23]. This suggests that a combination of indices may be appropriate in depicting hydration status[24].

Still and all, it is worth noting that health benefits of increasing water intake need to be evaluated in randomized control trials' investigating specific clinical outcomes. However, the number of studies reporting data on different potential biomarkers is limited. This situation is a clear limitation that reduced our ability to explore which population subgroups or in which types of intervention the biomarkers are effective.

Conclusion

Although several clinical studies have investigated the response of various biomarkers to changes in beverage intake, and important theoretical considerations have also been published[18,25-30], we still do not have enough data available in the literature to set robust biomarkers proxies to fluid intake.

Which biomarker might be sensitive enough to detect changes of a given dose of water in a given clinical condition or population group? Further research is needed to characterize and to understand the meaning of the different correlations between intake estimates and biomarkers of beverage in distinct population groups and environments.

Acknowledgements

Mariela Nissensohn and Lluis Serra-Majem contributed to the design of the strategy for the literature search. Lluis Serra-Majem prepared the main outline of the manuscript. Mariela Nissensohn selected the data and writing the manuscript. Cristina Ruano contributed to the selection of studies and data extraction. All authors contributed to the preparation of the final manuscript.

Authors acknowledge Daniel Fuentes Lugo from the Faculty of Health Sciences, Unacar, Ciudad del Carmen, Mexico and Daniela Cecic from the International Polytechnic Collage, Las Palmas de Gran Canaria, Spain, the support provided to assistance with the redaction of the paper.

Conflict of Interest Section

This study received a Grant from the European Hydration Institute (http://www.europeanhydrationinstitute.org). Neither Mariela Nissensohn nor Cristina Ruano report conflicts of interest to disclose. Lluis Serra-Majem serves at the Scientific Committee of the European Hydration Institute.

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