Title: Body weight impact of the sugar sweetened beverages tax in Mexican children: a modeling study.

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ABBREVIATIONS

SSBs, sugar-sweetened beverages; ENSANUT, Mexico National Health and Nutrition Survey; TEI, total energy intake; WHO, World Health Organization; T2DM, type 2 diabetes mellitus; BMI, body mass index; FFQ, food frequency questionnaire; DCGO, Dynamics of Childhood

Growth and Obesity Model; FM, fat mass; FFM, fat free mass; BW, body weight; CIs confidence intervals; NCDs, non-communicable diseases; CVD cardiovascular disease.

ABSTRACT

Background

In Mexico, a 10% tax to sugar sweetened beverages was implemented in 2014. Projections of the potential health effect of this tax in children are not available.

Objective

To estimate the one-year effect of the tax on the body weight of children 5 to 17 years-old, and estimated alternative scenarios with higher tax rates (20%, 30% and 40%).

Methods

We used a dynamical mathematical model, re-calibrated to the Mexican population. Input data was obtained from the Mexican National Health and Nutrition Survey 2006 and 2012. We estimated the expected average weight reduction, stratified by category of sugar sweetened beverages consumption.

Results

With a 10% tax, we estimated an overall weight reduction of 0.26 kg for children and 0.61 kg for adolescents; in high consumers, the reduction could reach 0.50 kg and 0.87 kg, respectively. Higher tax rates would produce larger weight decreases; in high consumers a 40% tax would result in a reduction of 1.99 kg for children and 3.50 kg for adolescents.

Conclusion

The tax represents an effective component of any child or adolescent weight control program, and must be considered as part of any integrated population-level program for children and adolescent obesity prevention.

INTRODUCTION

Sugar sweetened beverages (SSBs) are a primary source of added sugars in children and adolescents.[1] In the United States, SSBs contribute to 6.2% and 9.5% of the total energy intake (TEI) of children and adolescents.[2] In Mexico, soft drinks contribute to 6.8% of the TEI per day in children and 9.1% for adolescents;[3] thus, SSBs intake alone surpass the World Health Organization (WHO) ideal recommendation for daily free sugar consumption (5% TEI), and provide more than half of the current recommendation of 10% TEI.[1] Moreover, added sugars represent 13% of TEI in the Mexican diet and SSBs contribute with 69% of all added sugars.[4] Sugar consumption is increasingly recognized as a key target to improve population health, and reducing SSBs consumption is considered to be one of the most effective ways to substantially reduce total energy intake. [1,5,6]

There is substantial evidence showing that SSBs consumption causes adverse health outcomes in children and adolescents. SSBs consumption has been associated with dental caries, early menarche, and obesity.[6–9] Children affected by obesity at younger ages whom remain affected into adulthood, increase their risk of type 2 diabetes mellitus (T2DM), hypertension, dyslipidemias and atherosclerosis.[10] Avoiding SSBs consumption during childhood could provide important and long-lasting health benefits for children.[1,11] Recently, international organizations have recommended the implementation of specific interventions to reduce SSBs intake, such as excise taxes, reformulation, or SSBs bans in elementary schools.[11]

In 2014, Mexico implemented a 1 peso-per-liter tax for SSBs (10% approximate price increase), which led to an average purchase decrease of 7.6%.[12] These reductions are expected to produce important health benefits for adults, including the prevention of 189,000 cases of diabetes and 20,000 cases of cardiovascular disease, as well as a 2.6% reduction in the obesity prevalence in a decade.[13] However, Mexican children and adolescents are also high SSBs consumers [3], and will likely also benefit from SSBs reductions linked to the tax. A study by Ng et al. estimated that, after the tax was implemented in Mexico, high purchasers of taxed beverages experienced greater purchase reductions (-13.2%) compared to low purchasers (-0.4%).[14] To date, no study has attempted to estimate the health benefits of the SSBs tax in children and adolescents in Mexico.

We aimed to estimate the potential impact of Mexico's SSBs tax in children and adolescents. We implemented a dynamical model of childhood growth and obesity, re-calibrated to Mexican children, to estimate the expected one-year body weight change, assuming that the observed reduction in SSBs purchases reflected changes in SSBs consumption. The model was developed using Mexican nationally representative estimates of SSBs consumption, weight, sex and age. We estimated the potential effect with the current tax and estimated alternative tax scenarios to explore the potential impact of strengthening the policy.

METHODS

We obtained baseline SSB consumption, and anthropometric measurements, among children in Mexico using the 2012 National Health and Nutrition Survey (ENSANUT). The ENSANUT 2012 is a cross-sectional, multistage, probabilistic survey representative of the Mexican population that measures the health and nutrition status in the Mexican population. The study protocol, questionnaires, and informed consent procedures for the 2012 National Survey of Health and Nutrition approved by the ethics, research and biosecurity committee of the National Institute of Public Health. All children and adolescents provided assent to participate in the study, in addition to parental written consent.[15]

Model inputs

Anthropometric measurements

All anthropometric measurements were obtained following standardized procedures and instruments.[16] Individuals with implausible body mass index (BMI) <10 kg/m2 or >58 kg/m^2 and pregnant adolescents were excluded from the analysis.[17] Our final analytical sample consisted of a total of 1,123 school age children (5 to 11 yrs.); and 1,390 adolescents (12 to 18 yrs.).

Dietary intake

We used ENSANUT's seven-day semi-quantitative food frequency questionnaire (FFQ) to calculate SSBs consumption and TEI (kcal/day). The questionnaire was administered to mothers or caretakers of school age children; adolescents self-reported their food consumption.

Details about ENSANUT's FFQ methodology are available elsewhere.[18] SSBs intake was obtained by adding the estimated daily consumption (Kcal) of four taxed SSBs: soda, industrialized natural fruit juice with added sugar, industrialized beverage or flavored water, and industrialized fruit nectar. Following the work of Ng and colleagues, we classified children as low consumers if their SSBs intake was lower than 150.3 ml/day, and as high consumers if their intake was 150.3 ml or higher. TEI was obtained from the FFQ; we excluded individuals that reported implausible values of daily TEI (<500 Kcal or >7000 Kcal).[19]

Tax impact by SSB consumption level

Based on the evidence from Ng, et al.,[14] we estimated the weighted average relative purchase change of the combined sets of all higher and all lower purchasers of taxed beverages after the Mexican tax. We obtained an average purchase change of -8.1% and -2.0% in 2014 and -18.2% and 1.3% in 2015 for high consumers and low consumers, respectively. This yielded an average purchase decline of -13.2% for high consumers and -0.4% for low consumers in both years.

Model simulations

For our main analyses we present the change in weight after one-year SSBs tax implementation, simulating the impact of four potential tax scenarios: 10%, 20%, 30% and 40%, assuming null caloric compensation from other beverages.

The Dynamics of Childhood Growth and Obesity Model (DCGO) proposed by Hall and colleagues,[20] has been previously validated with experimental weight data.[21,22] This model predicts changes in weight over time *(t)* using a system of two differential equations to predict fat mass (*FM(t)*) and fat free mass (FFM*(t)*). The sum of *FM*(*t*) and *FFM*(*t*) provides the predicted body weight (*BW(t)*) at time *t*. For the *BW(t)* calculation, we also considered the relation between energy intake rate and energy expenditure, adjusted by a growth term. All these variables are dependent on individual characteristics, such as age, sex, initial body weight, height and other parameters that account for the complex physiological processes that occur during childhood and adolescence. The DGCO model does not provide confidence intervals (CIs) to the estimated weight change, therefore our CIs only consider the sources of error captured by the survey data. A more detailed description of the DCGO model, sensitivity analyses, data sources for inputs used and algorithm implementation, are presented in the supplementary materials (S1 Appendix).

Sensitivity analyses

In the main analysis, we assumed no energy compensation and a range of possible taxation levels from 10% to 40%. In real life, caloric compensation could vary due to intermeal interval and energy density of foods.[23] Therefore, we decided to conduct a sensitivity analysis to estimate the potential impact of different SSBs tax scenarios (from 0 to 100%) in combination with different compensation rates (from 0% to 100%). Although the tax scenarios considered in this paper vary between 10%-40%, for the purpose of the sensitivity analysis we used the whole range from 0% to 100%, similarly, we used caloric compensation rates between 0% and 100%. No evidence exists of caloric compensation when replacing SSBs with water. However, we considered a study by Katan et al. that estimated caloric compensation rates by replacing

SSBs with sugar free beverages, ranging from 13% to 65%.[24] The most plausible scenarios are shown within the red box in Figure 2 (tax from 10% to 40% and caloric compensation from 0% to 70%).

RESULTS

Table 1 shows the proportion of the population in each level of SSBs consumption and the average baseline proportion of TEI from SSB consumption, reported in ENSANUT 2012. Overall, 38.5% were low consumers and high consumers represent 61.5% of the population. On average, 6.9% of the total energy intake comes from SSB consumption for the whole children and adolescent population. The proportion of energy intake from SSBs for low consumers was 2.2% and goes up to 9.9% for high consumers. This proportion is slightly different between children and adolescents, for each level of consumption, with adolescents having a higher proportion of energy intake from SSBs than young children.

Table 2 presents expected caloric intake reduction after the implementation of a 10% tax. Considering the average tax effect of each level of consumption, total energy intake was expected to decrease 17.56 kcal/person/day for the whole children and adolescent population. Among low consumers, the reduction could be less than 1 kcal/person/day, while high consumers could reach up to 29.21 kcal/person/day with an SSBs tax of 10%. We observed an average reduction of 11.69 kcal/person/day and 24.44 kcal/person/day for children and for adolescents, respectively.

Table 3 presents the 1-year expected reduction in body weight under the four tax scenarios, for children and adolescents, considering their baseline SSBs consumption (low, high). Counterfactual body weight is the one-year predicted body weight of ENSANUT 2012, using the DCGO model without intervention. We can observe that the gap between low and high consumer's counterfactual body weight is 5.47 kg. Under the current 10% tax scenario, the average body weight reduction is expected to be 0.42 kg; high consumers are expected to lose 0.70 kg, while low consumers body weight reduction is virtually zero. As the tax increases, the expected body weight reductions become larger. At a 40% tax, the average body weight reduction is expected to reach 1.68 kg in the first year. This decrease is larger in high SSBs consumers, whom under the 40% tax are expected to experience a 2.80 kg reduction. Dividing high consumers into children and adolescents, we can observe an average body weight reduction of 0.50 kg and 0.87 kg respectively, with a 10% tax. This could go up to 1.99 kg reduction for children and 3.50 kg for adolescents with a 40% tax.

Figure 1 shows predicted change in body weight for children and adolescents one year after the implementation of the SSBs tax. The figure illustrates four different tax scenarios, ranging from 10% to 40%. For children, we projected a 0.26 kg body weight reduction with a 10% tax, which could reach 1.03 kg assuming a 40% tax. For adolescents, the body weight reduction with a 10% tax would be 0.61 kg, increasing to 2.46 kg at 40%.

Figure 2 shows the results of our one-year sensitivity analysis, testing different tax levels in combination with various compensation rates. Overall, we observed that the potential effect of taxation on body weight reduction could range between 0.42 kg with a 10% tax to 4.28 kg with a 100% tax, assuming no caloric compensation. Nonetheless, even with a high caloric compensation (60%), we could still observe average potential body weight reductions that could vary between 0.17 kg to 1.68 kg with 10% and 100% taxes, respectively. The most plausible scenarios are shown inside the red box.

DISCUSSION

We estimated the potential body weight reduction for children one year after the implementation of the SSBs tax in Mexico. Under the current 10% SSB tax, children and adolescents should have experienced an average reduction in body weight over the first year of 0.26 kg and 0.61 kg, respectively. For higher SSB consumers, we expect an average body weight reduction of 0.50 kg for children and 0.87 kg for adolescents, which could be 1.99 kg for children and 3.50 kg for adolescents with a 40% tax. These body weight changes, if maintained during childhood and into adulthood could provide important short and long-term benefits, such as improvements in cardiovascular risk factors (lower triglycerides and low-density lipoprotein-cholesterol), and insulin sensitivity.[25–27]

High consumption of SSBs plays an important role in the development of non-communicable diseases (NCDs). Several biological mechanisms link the consumption of SSBs with increased body weight gain and risk of many NCDs. The high sugar content of SSBs and liquid calories do not suppress appetite and energy intake in subsequent meals, as do calories consumed as solid foods. This leads to additional energy intake, which can result in body weight gain.[6,28]

This continuous energy imbalance causes a chronic inflammatory state, which generates a sustained release of leukocytes into the adipose tissue, contributing to the development of insulin resistance and NCDs like type 2 diabetes.[29] Furthermore, the presence of obesity can cause resistance to leptin, a hormone which intervenes in different physiological processes such as: regulation of appetite and energy balance and fat metabolism.[30] All of the above generate a chronic cycle of high energy consumption with low expenditure, aggravating body weight gain and increasing the risk of obesity.

Overweight and obesity during childhood are strong predictors for obesity later in life.[31] Nearly 50% of children with high BMI will become adults with obesity.[31] Moreover, recent evidence shows that childhood obesity increases the risk of NCDs at younger ages.[32] For example, in the US, nearly 70% of children with obesity have at least one cardiovascular risk factor and 40% at least two risk factors, compared with normal body weight children.[33] In addition, high BMI in childhood or adolescence has been associated with higher blood pressure and cholesterol levels at younger ages and with higher cardiovascular disease (CVD) risk later in adulthood.[34,35] Given the above, it is very important to prevent body weight gain at an early age. Our results suggest that taxing SSBs could provide a new tool for the prevention of body weight gain at early ages, although many other additional population and individual strategies will be required to reduce the current burden of obesity in children in Mexico.[17] Regulatory efforts, such as the restriction of junk food sales in schools,[36] shifting the current front of pack food labels used in Mexico,[37] which are not effective, to warning labels such as the ones used in Chile,[38] banning

SSB´s advertisement to children or reformulating SSBs[39] are all promissory avenues for obesity prevention in children, which should be consider all in tandem as part of a global strategy.

To the best of our knowledge, this is the first study to individually estimate the expected impact of a nutritional-based intervention on body weight, that takes into account a growth factor among children and adolescents. A recent study in Mexican children by Basto-Abreu, et al. estimated the future impact of SSB tax among children and adolescents. Assuming the average annual decrease of SSB (7.6 percent), they estimated an approximate caloric intake reduction of -7.3 kcal/person/day that yields a reduction of 94,000 cases of obesity for 10 years; no comparable body weight change was available.[40] In contrast, our results showed an overall caloric reduction of -17.56 kcal/person/day. However, these estimates are not directly comparable; Basto-Abreu, et al., modeled the overall tax impact in consumption, while we used the more recent estimates that take into consideration the differential impact of the tax by levels of consumption.

Smith, et al., simulated a 20% tax for one year in US children and adolescents, and estimated a reduction of 2.00 kg.[41] Assuming a 20% SSBs tax, we estimated that children and adolescents could reduce their body weight by 0.84 kg. Children and adolescent growth is a complex process; it involves different age dependent energy needs that, if modified by internal and/or external factors, could encourage excess body weight gain. The existing simulation literature for these age groups, fails to consider the physiological effect of natural growth and its impact on energy requirements.[20] The use of a dynamic model that explicitly considers a growth factor and individual changes, could explain the differences in our estimates with those previously reported.

Our analysis adds to the emerging evidence about the potential health benefits of SSBs taxes.[13,40] This study complements earlier studies in adults and jointly considers dietary data, fat mass, and fat free mass estimates from Mexican children using a validated model for children body weight change calibrated to the Mexican population. However, our study has several limitations. Dietary intake data from the seven-day FFQ may underestimate total energy intake; ENSANUT's FFQ was answered by the primary caregiver in children 11 years old and younger. The caregiver could not have been fully aware of the food consumed at school,[42] which could lead to the underestimation of energy intake. Reporting error of dietary intake is also influenced by body weight status, particularly in adolescents with obesity.[43] Despite this limitation, the FFQ is a valid tool to estimate ranges of energy intake and energy from food groups, and, given that it tends to underestimate consumption, it can be interpreted as being conservative.[44]

There is uncertainty as to how much of the energy from SSBs reduction will be translated into an overall caloric reduction, considering that some of the calories reduced through the tax could be substituted by other foods or beverages. Our analysis assumes that the reduction in SSB consumption will be substituted by water; however, there is always the possibility of children substituting SSBs by nonnutritive sweeteners. It is unclear if nonnutritive sweeteners increase body weight in children.[45] If that were the case, our estimates would overestimate the impact of the tax, even in the absence of caloric substitution. Potential substitution estimates go from no substitution (assuming SSBs do not affect satiety, being less likely to be substituted by food) to a 43% substitution that has been observed in adults.[46] Considering this large range of potential values, we conducted a sensitivity analysis for the effects of various tax levels and substitution scenarios; under 0% substitution and the current 10% tax, the average body weight reduction amounts to 0.42 kg, which could be reduced to 0.21 kg if substitution were to be 50%. Further studies are needed to better inform substitution in children under this type of intervention. Furthermore, the DCGO model is designed to predict children's body weight from 5 to 18 years of age. For our analysis, we used data simulating a closed cohort. For this reason, we estimated a one-year impact, because increasing the period would reduce our analytic sample, as adolescents reach adulthood. As a sensitivity analysis, we estimated the body weight impact over 3 years, using the 5-15 year old's subsample; we could expect an average body weight reduction 0.48 kg over the three years following the implementation of the tax (S1 Appendix figure 4), with 87.4% of the total reduction occurring in the first year.

Our study suggests that the current SSBs tax could represent an effective national policy to reduce body weight in children and adolescents. For high SSBs consumers, which represent 61.5% of the total population, the current 10% tax would produce sizable body weight reductions. Following the WHO recommendation of a 20% tax,[11] our results showed an average body weight reduction of 1.39 kg in high consumers; this could go up to 2.80 kg with a hypothetical 40% tax in high SSBs consumers. These findings suggest that increasing the tax is a key step to further reduce body weight and prevent children and adolescent obesity.

SSBs taxes need to be consistently included as part of the public health strategies to reduce obesity globally. Currently, 19 countries including Mexico have implemented SSBs taxes as part of an integral strategy to reduce obesity, largely focusing in the health benefits for adults.[47] Our results suggest that SSBs taxes could also be beneficial for children and adolescents, helping to reduce the future burden of chronic diseases. Other efforts, such as food labeling or sugar reformulation, will be needed to change the childhood obesity landscape.

CONFLICT OF INTEREST

The authors have declared that no competing interests exist.

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administration, resources, software, supervision, validation, visualization, wrote, reviewed and edited the original draft. All authors were involved in writing the paper and had final approval of the submitted and published versions.

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Table 1. Baseline proportion of total energy intake (TEI) from sugar sweetened beverages in Mexican children from ENSANUT 2012.

Type of consumer	N (%)	Baseline proportion of TEI from SSB consumption (%) (95% CI)		
		All	**6 to 11**	**12 to 18**
All	2374 (100%)	6.9% (6.6%, 7.3%)	5.6% (5.2%, 6.1%)	8.0% (7.5%, 8.6%)
Low	915 (38.5%)	2.2% (2.1%, 2.3%)	2.2% (2.0%, 2.3%)	2.2% (2.0%, 2.4%)
High	1459 (61.5 %)	9.9% (9.4%, 10.4%)	8.8% (8.1%, 9.5%)	10.6% (9.9%, 11.2%)

Low SSBs consumption (< median of SSB consumption); **High SSBs consumption** (≥ median of SSB consumption).

Table 2. Estimated caloric intake reductions after the implementation of a 10% SSB tax increase.

Type of consumer	Caloric intake reduction with a 10% tax (kcal/person/day) (95% CI)		
	All	**6 to 11**	**12 to 18**
All	-17.56 (-18.81, -16.31)	-11.69 (-12.89, -10.48)	-24.44 (-26.60, -22.28)
Low	-0.19 (-0.20, -0.18)	-0.17 (-0.18, -0.16)	-0.22 (-0.24, -0.20)
High	-29.21 (-30.77, -27.64)	-22.62 (-24.21, -21.03)	-34.87 (-37.29, -32.45)

Low SSBs consumption (< median of SSB consumption); **High SSBs consumptio**n (≥ median of SSB consumption).

Table 3. Expected body weight reduction in children and adolescents one year after the implementation of the SSB tax in Mexico.

Age group	Type of consumer	Counterfactual body weight†	Reduction in body weight due to the tax (kg) (95% CI)			
			10%	20%	30%	40%
All	**All**	46.22 (45.40, 47.04)	-0.42 (-0.45, -0.39)	-0.84 (-0.90, -0.78)	-1.26 (-1.35, -1.17)	-1.68 (-1.81, -1.56)
	Low	42.95 (41.73, 44.17)	0.00 (0.00, 0.00)	-0.01 (-0.01, -0.01)	-0.01 (-0.01, -0.01)	-0.02 (-0.02, -0.02)
	High	48.42 (47.38, 49.46)	-0.70 (-0.73, -0.66)	-1.39 (-1.47, -1.32)	-2.10 (-2.21, -1.98)	-2.80 (-2.96, -2.65)
6 to 11	**All**	35.71 (35.06, 36.35)	-0.26 (-0.28, -0.23)	-0.51 (-0.57, -0.46)	-0.77 (-0.85, -0.69)	-1.03 (-1.13, -0.92)
	Low	35.20 (34.29, 36.11)	0.00 (0.00, 0.00)	-0.01 (-0.01, -0.01)	-0.01 (-0.01, -0.01)	-0.01 (-0.02, -0.01)
	High	36.18 (35.28, 37.08)	-0.50 (-0.53, -0.46)	-0.99 (-1.06, -0.92)	-1.49 (-1.60, -1.39)	-1.99 (-2.13, -1.85)
12 to 18	**All**	58.55 (58.10, 58.99)	-0.61 (-0.66, -0.55)	-1.22 (-1.33, -1.11)	-1.84 (-2.00, -1.67)	-2.46 (-2.67, -2.24)
	Low	57.65 (56.94, 58.35)	-0.01 (-0.01, 0.00)	-0.01 (-0.01, -0.01)	-0.02 (-0.02, -0.01)	-0.02 (-0.02, -0.02)
	High	58.93 (58.38, 59.49)	-0.87 (-0.93, 0.81)	-1.74 (-1.86, -1.62)	-2.62 (2.80, 2.44)	-3.50 (-3.75, -3.26)

Low SSBs consumption (< median of SSB consumption); **High SSBs consumption** (≥ median of SSB consumption). † **One-year counterfactual body weight** without intervention.

Table 1. Baseline proportion of total energy intake (TEI) from sugar sweetened beverages in Mexican children from ENSANUT 2012.

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Table 2. Estimated caloric intake reductions after the implementation of a 10% SSB tax increase.

Table 2. Low SSBs consumption (< median of SSB consumption); **High SSBs consumption** (≥ median of SSB consumption).

Table 3. Expected body weight reduction in children and adolescents one year after the implementation of the SSB tax in Mexico.

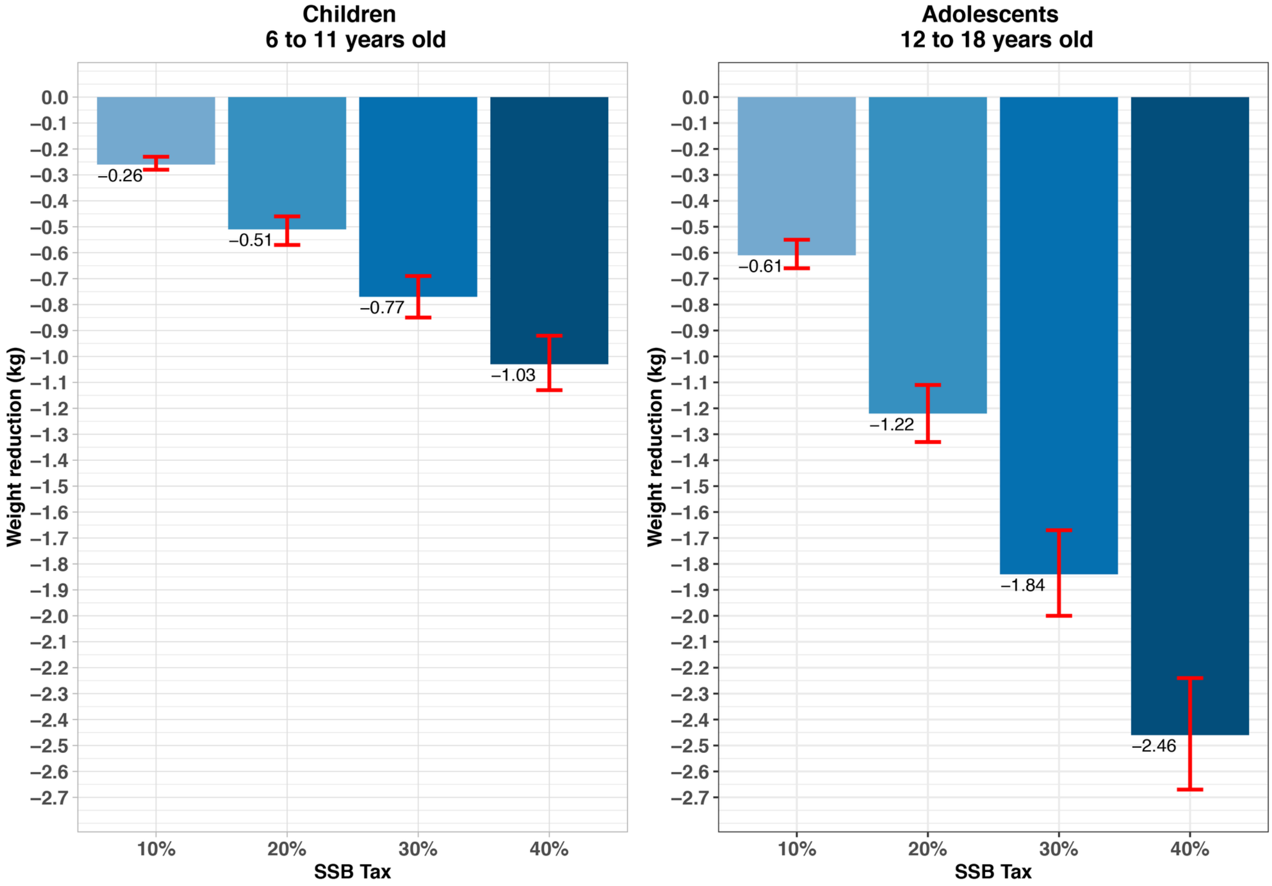
Table 3. Low SSBs consumption (< median of SSB consumption); **High SSBs consumption** (≥ median of SSB consumption). † **One-year counterfactual body weight** without intervention.

Figure 1. Expected body weight reductions one year after the implementation of the 10% sugar sweetened-beverages tax in Mexico, and alternative scenarios (20 to 40% tax) in children and adolescents.

Figure 1. The red error bar represents 95% confidence intervals.

Figure 2. Sensitivity analysis for estimated body weight (kg) change after one year, based on different sugar reductions and compensation rates.

Figure 2. The red box contains the most plausible scenarios (tax from 10% to 40% and caloric compensation from 0% to 70%).



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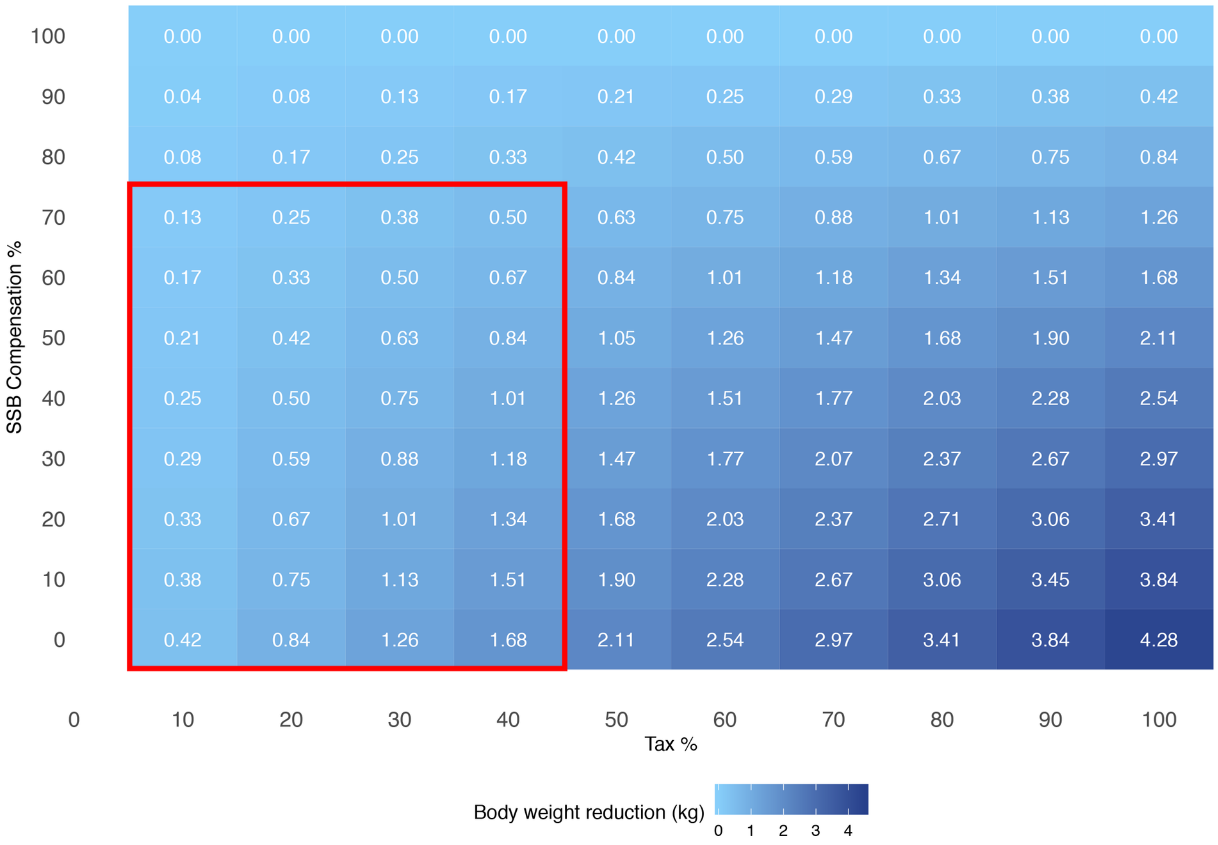

	10	20	30	40	50	60	70	80	90	100
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.04	0.08	0.13	0.17	0.21	0.25	0.29	0.33	0.38	0.42
80	0.08	0.17	0.25	0.33	0.42	0.50	0.59	0.67	0.75	0.84
70	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.01	1.13	1.26
60	0.17	0.33	0.50	0.67	0.84	1.01	1.18	1.34	1.51	1.68
50	0.21	0.42	0.63	0.84	1.05	1.26	1.47	1.68	1.90	2.11
40	0.25	0.50	0.75	1.01	1.26	1.51	1.77	2.03	2.28	2.54
30	0.29	0.59	0.88	1.18	1.47	1.77	2.07	2.37	2.67	2.97
20	0.33	0.67	1.01	1.34	1.68	2.03	2.37	2.71	3.06	3.41
10	0.38	0.75	1.13	1.51	1.90	2.28	2.67	3.06	3.45	3.84
0	0.42	0.84	1.26	1.68	2.11	2.54	2.97	3.41	3.84	4.28

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Instructions

The purpose of this form is to provide readers of your manuscript with information about your other interests that could influence how they receive and understand your work. The form is designed to be completed electronically and stored electronically. It contains programming that allows appropriate data display. Each author should submit a separate form and is responsible for the accuracy and completeness of the submitted information. The form is in six parts.

1. Identifying information.

2. The work under consideration for publication.

This section asks for information about the work that you have submitted for publication. The time frame for this reporting is that of the work itself, from the initial conception and planning to the present. The requested information is about resources that you received, either directly or indirectly (via your institution), to enable you to complete the work. Checking "No" means that you did the work without receiving any financial support from any third party -- that is, the work was supported by funds from the same institution that pays your salary and that institution did not receive third-party funds with which to pay you. If you or your institution received funds from a third party to support the work, such as a government granting agency, charitable foundation or commercial sponsor, check "Yes".

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This section asks about patents and copyrights, whether pending, issued, licensed and/or receiving royalties.

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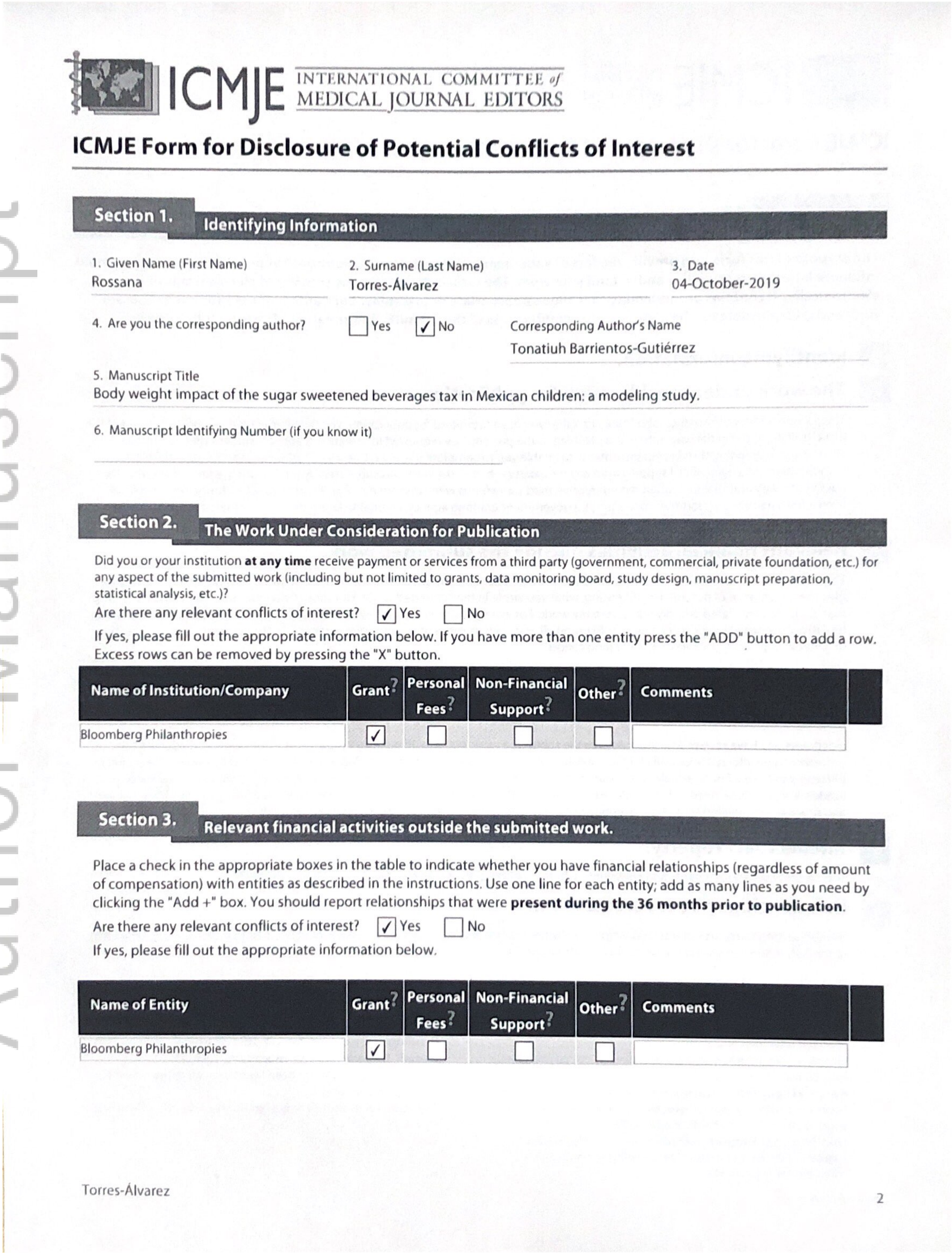

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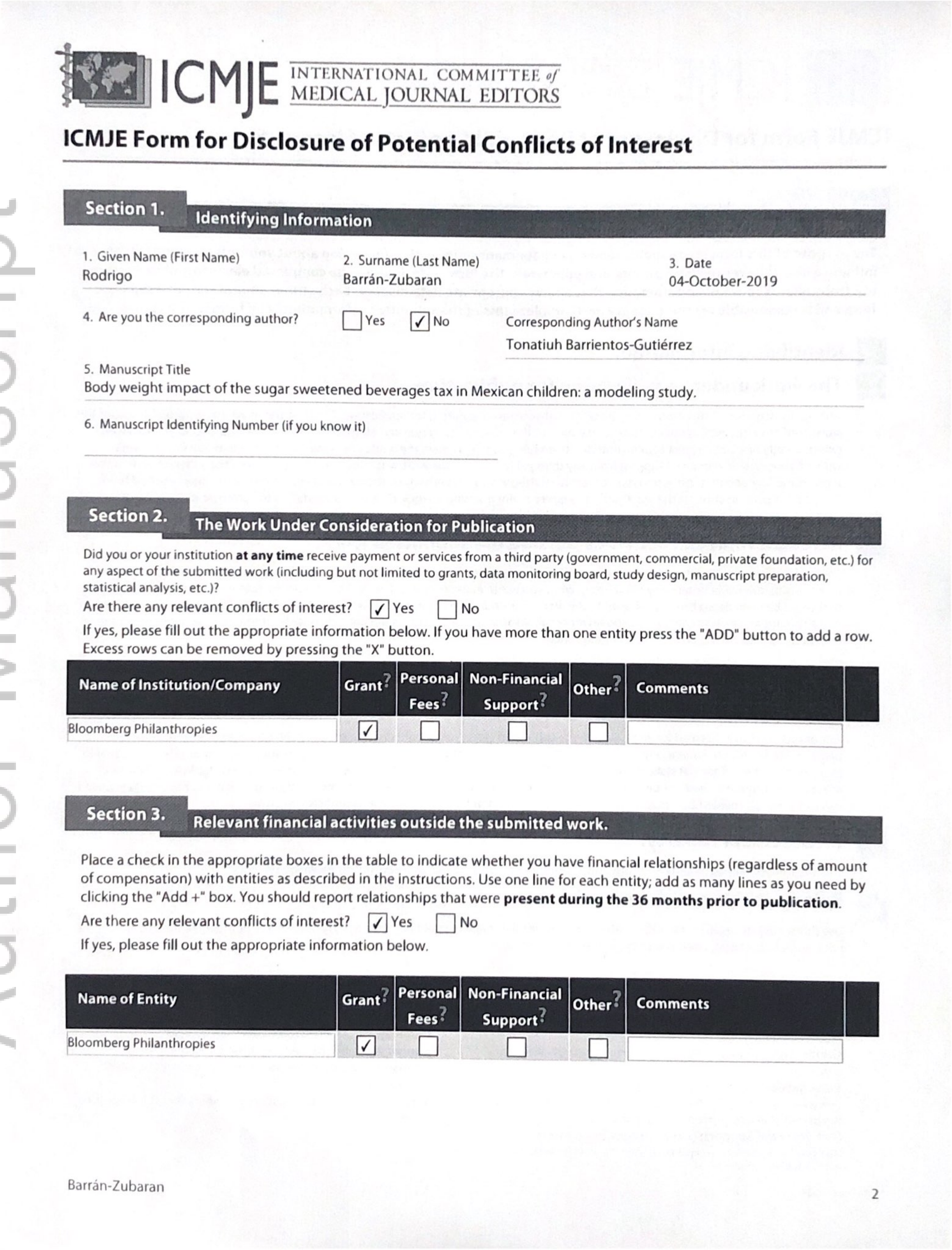

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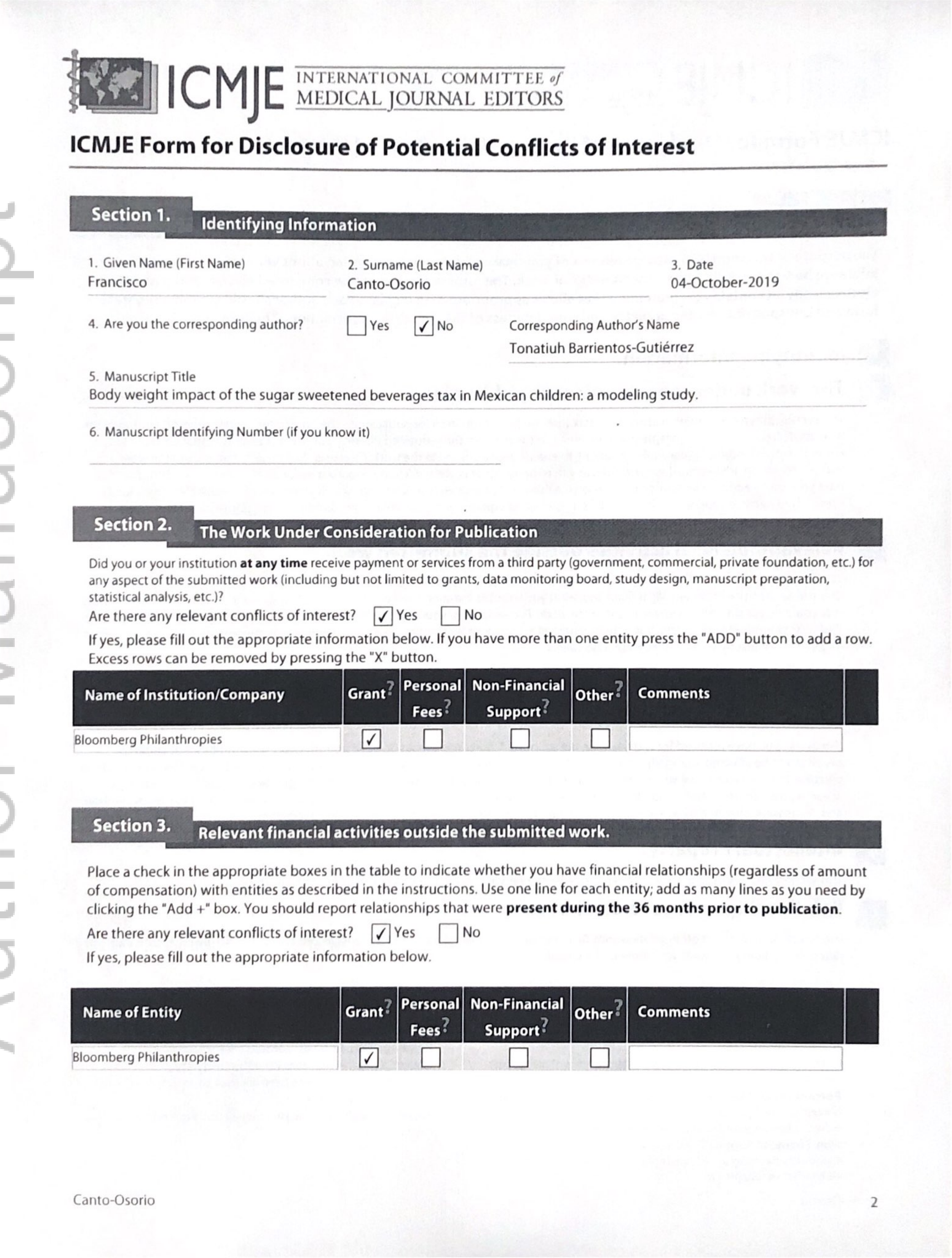

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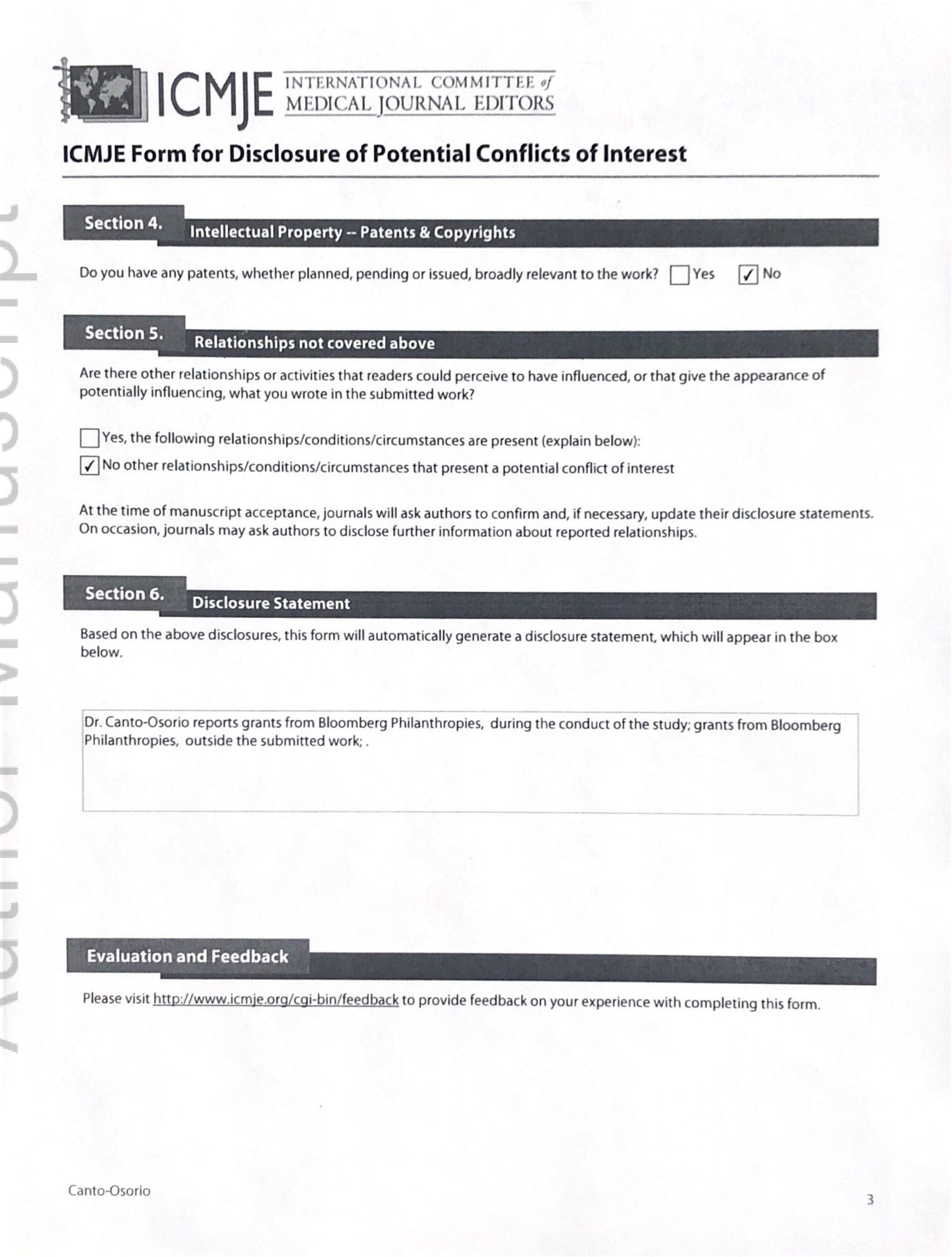

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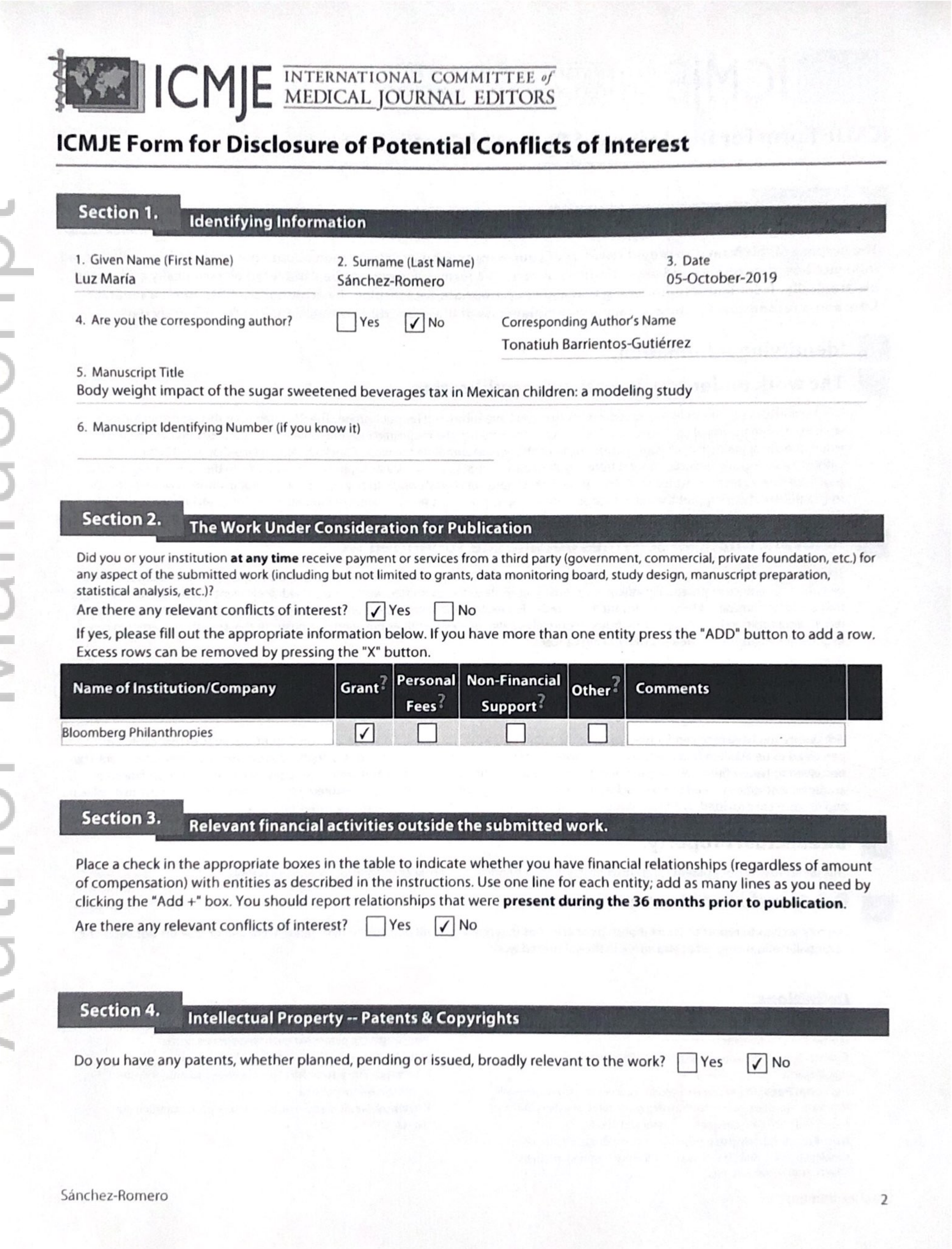

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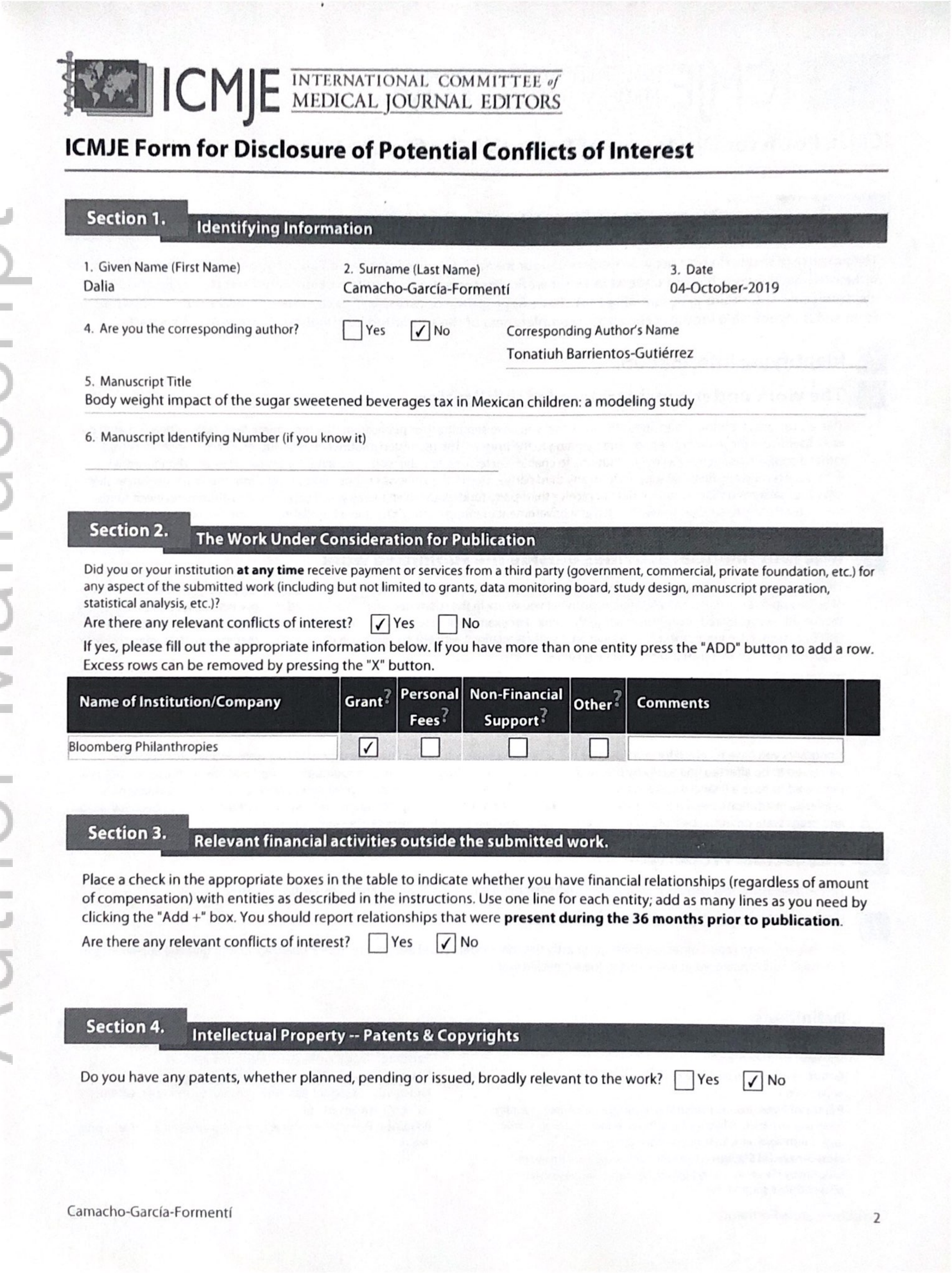

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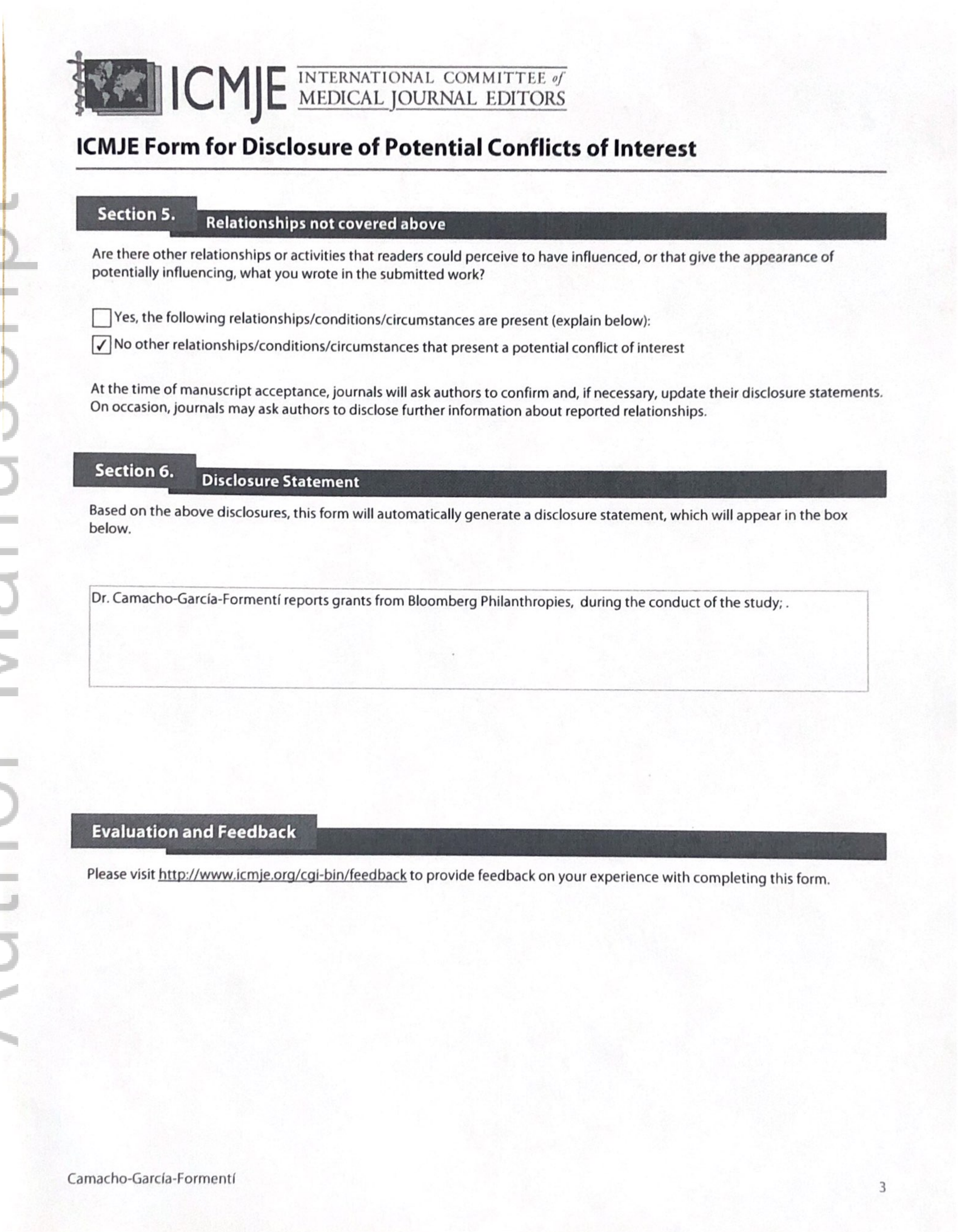

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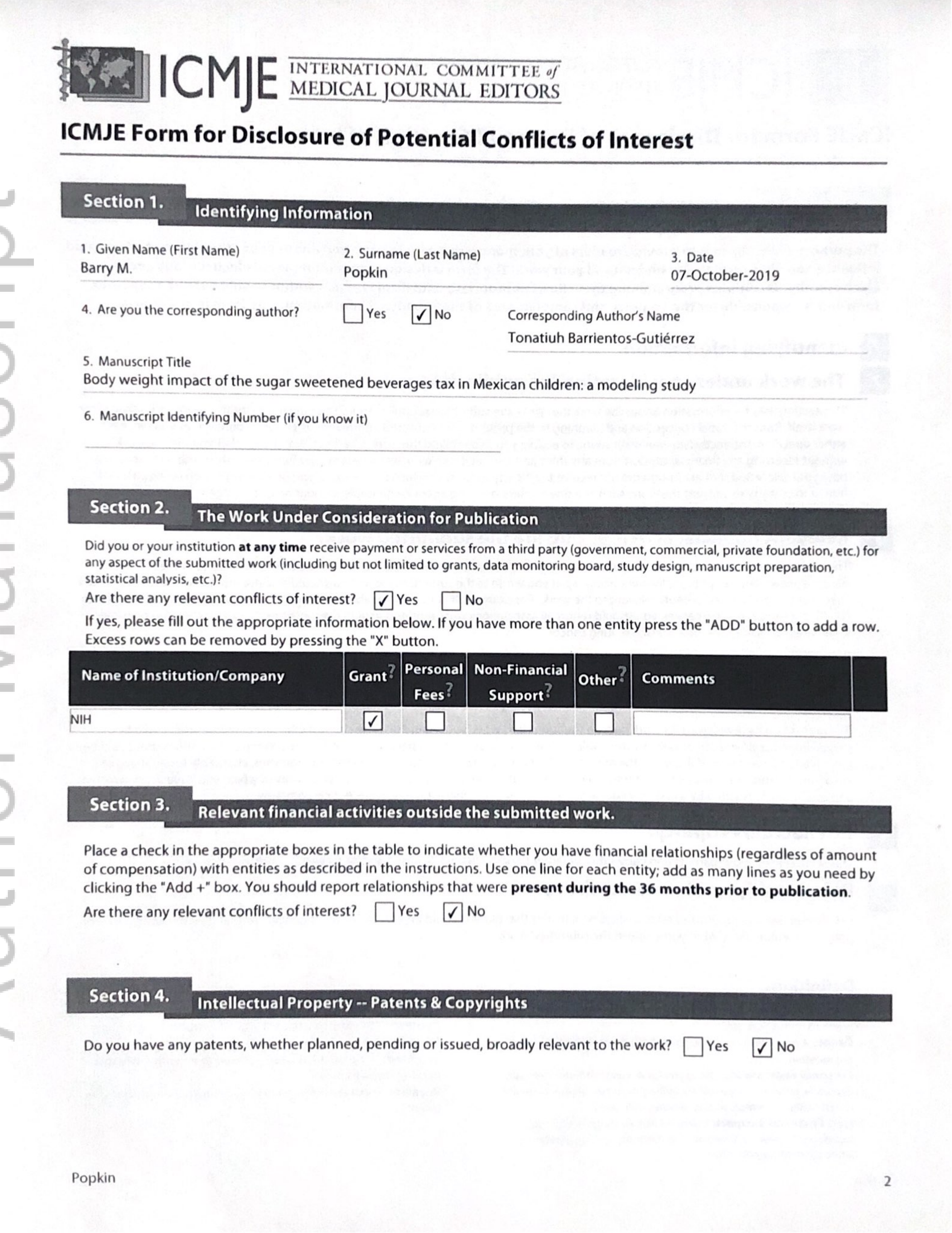

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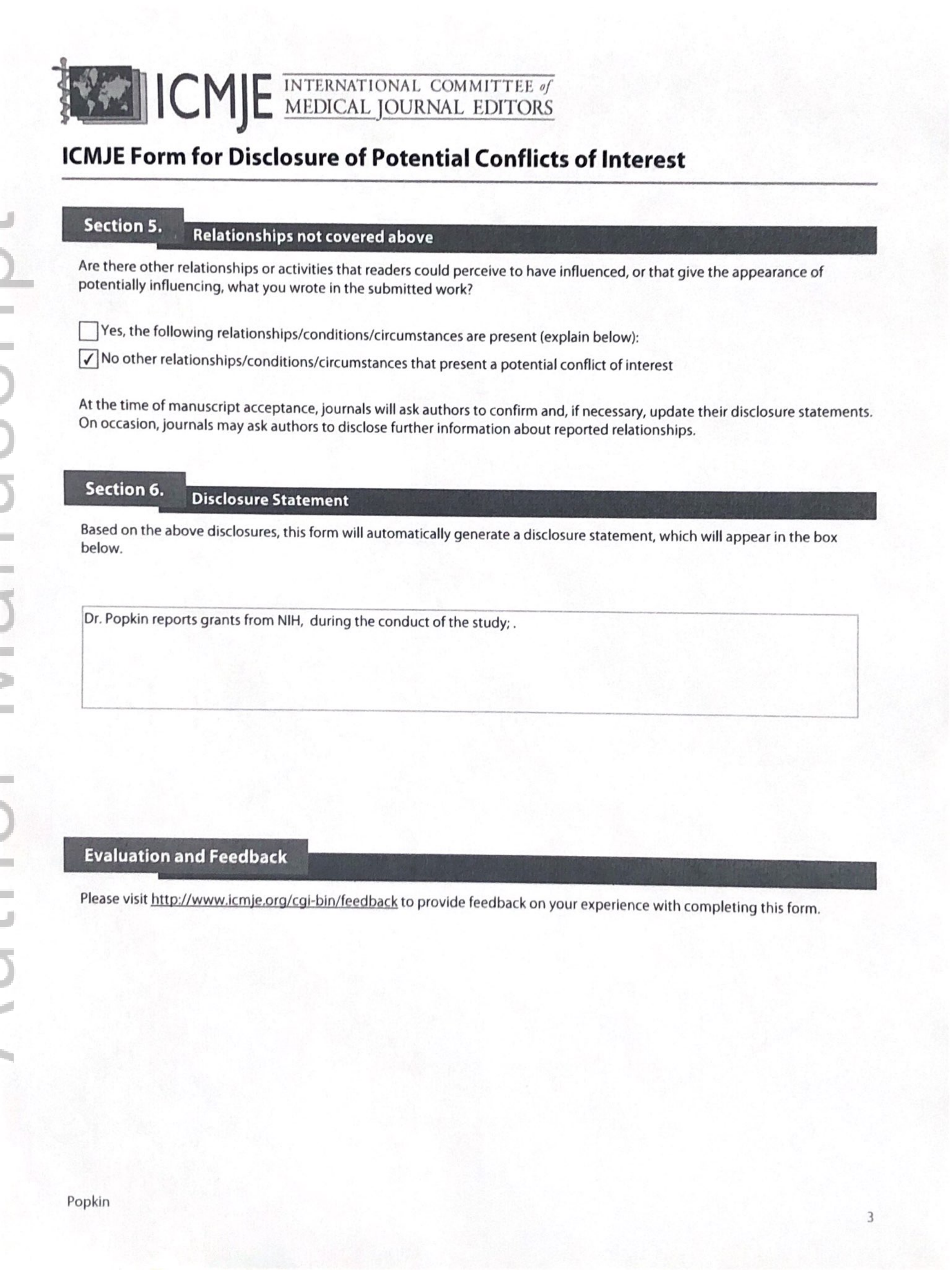

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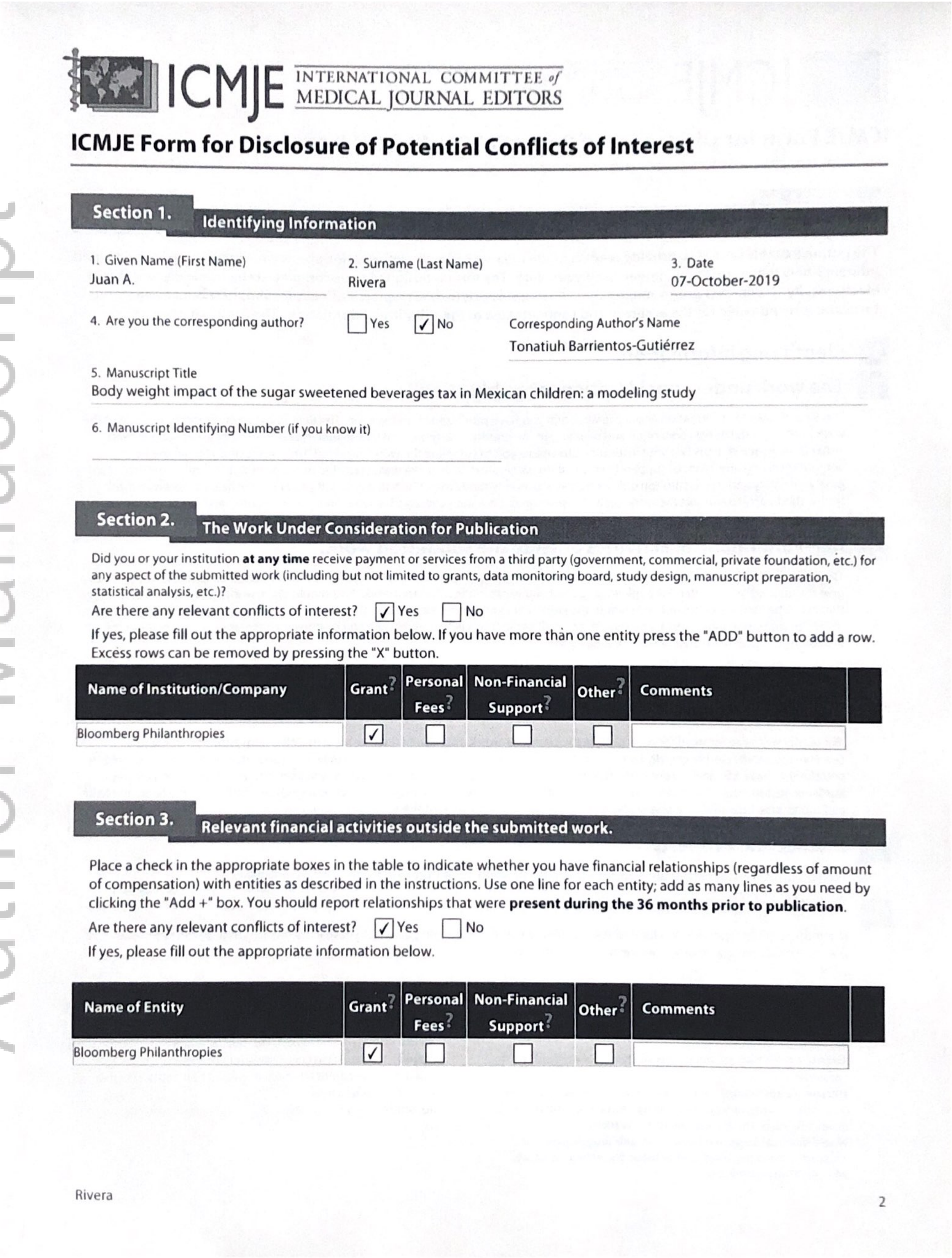

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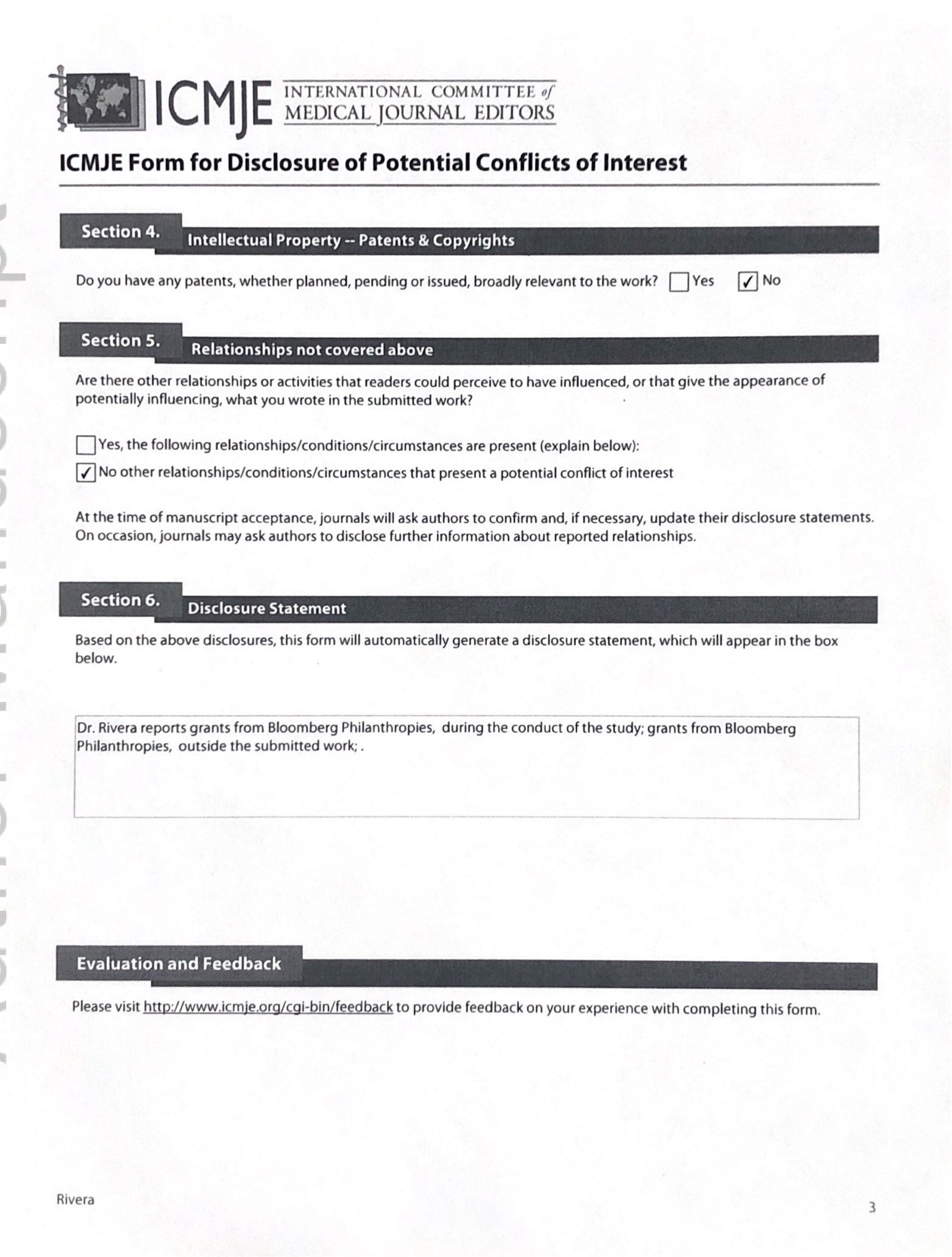

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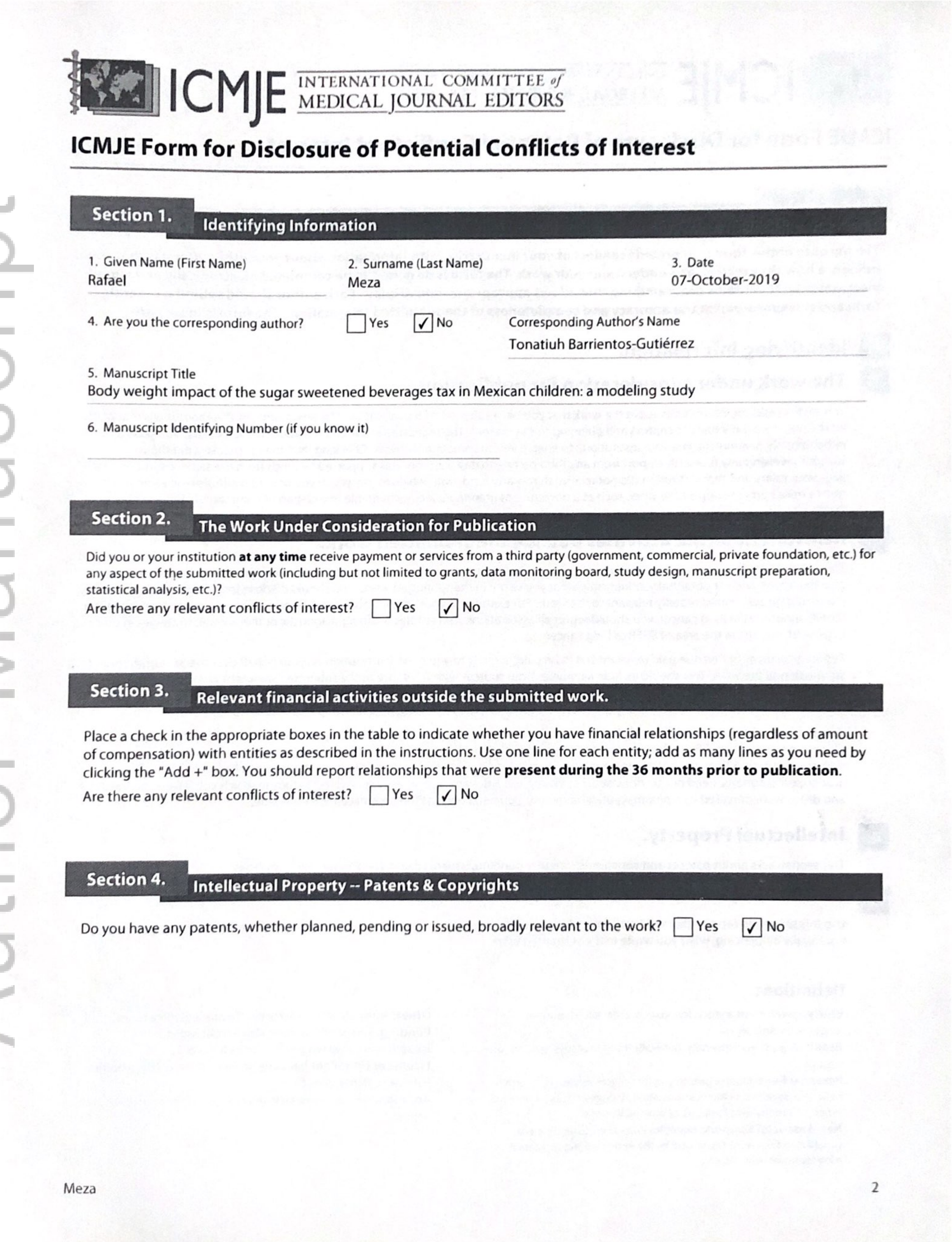

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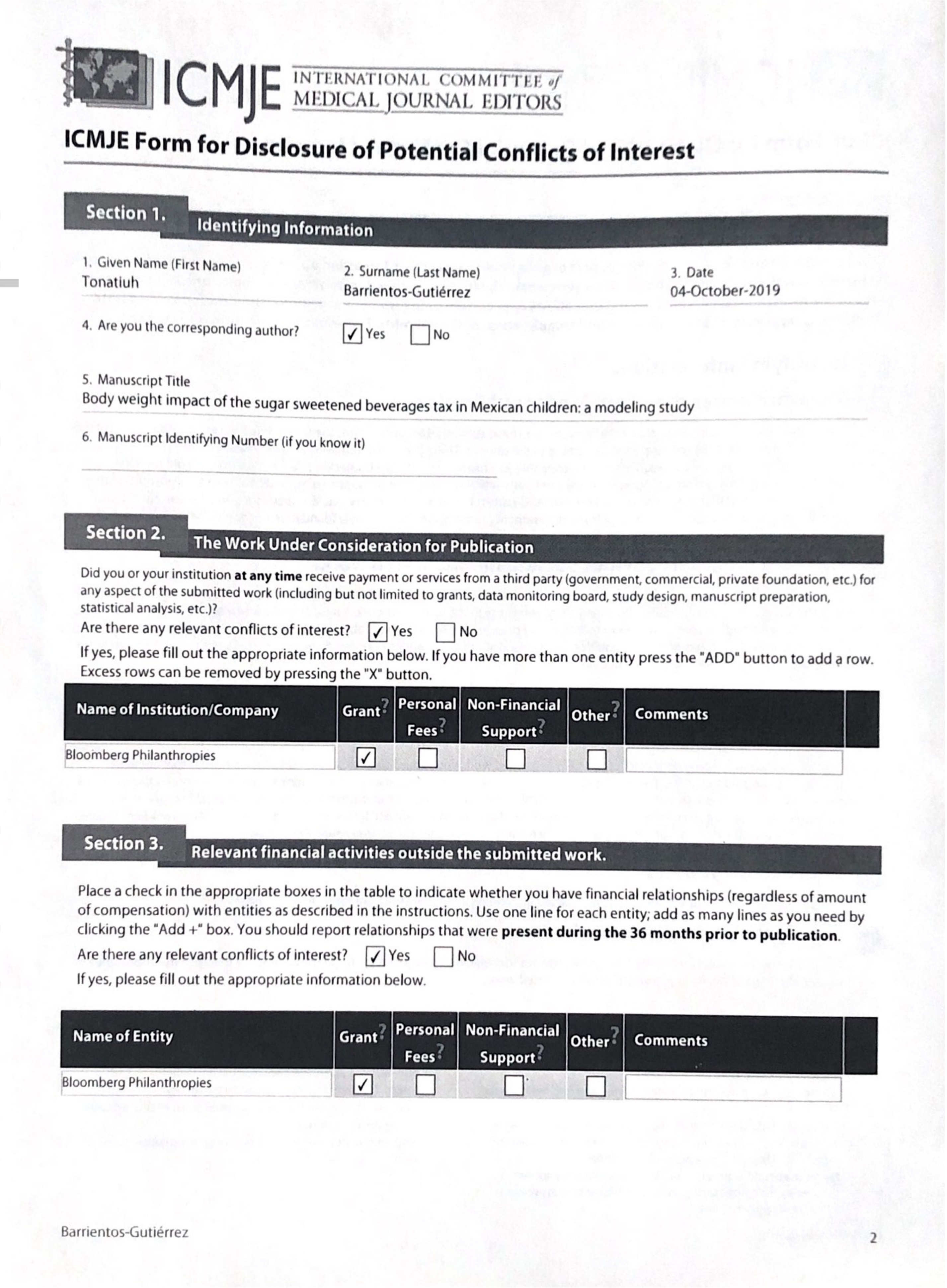

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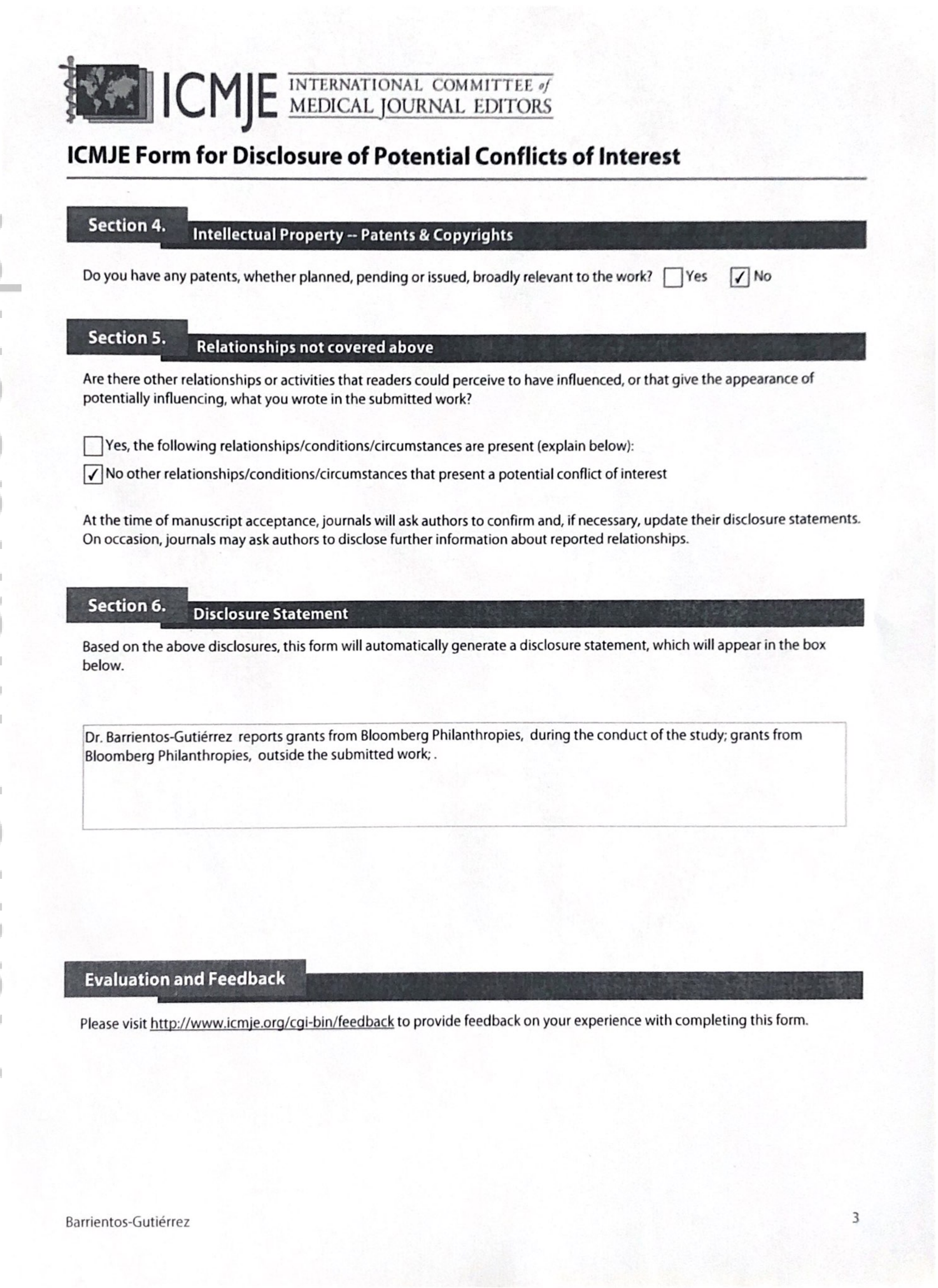

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Body weight impact of the sugar sweetened beverages tax in Mexican children: a modeling study

Rossana Torres-Álvarez[1], Rodrigo Barrán-Zubaran[1], Francisco Canto-Osorio[1], Luz María Sánchez-Romero[2], Dalia Camacho-García-Formentí[1], Barry M. Popkin[3], Juan A. Rivera[4], Rafael Meza[5], and Tonatiuh Barrientos-Gutiérrez *[1]

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Contents

1 Weight change model

We adapted the Dynamics of Childhood Growth and Obesity model (DCGO) from Hall et al., and Katan et al.,[1, 2] to the Mexican population. Briefly, this physiological weight change model considers the interactions between **fat mass**, $FM := FM(t)$, **fat free mass**, $FFM := FFM(t)$, an **energy intake** function, $I := I(t)$, and an **energy expenditure** function, $E := E(t)$, adjusted by a **body-growth term**, $g(t)$. In this model, **body weight** is given by the sum of **fat mass** and **fat free mass**:

$$BW := BW(t) = FM(t) + FFM(t). \tag{1}$$

In particular, **body weight** (BW) is a function of time t, depends on the individual's characteristics for **sex** (Sex), **initial fat mass** (FM_0), **initial fat free mass** (FFM_0) and **energy intake** ($I(t)$).This is represented as:

$$BW := BW\big(t; \text{Sex}, FM_0, FFM_0, I(t)\big). \tag{2}$$

The components of BW, FM and FFM are determined by a system of ordinary differential equations:

$$\begin{aligned} \hat{\rho}_{FFM} \cdot \frac{dFFM}{dt} &= p \cdot (I - E) + g(t), \\ \rho_{FM} \cdot \frac{dFM}{dt} &= (1-p) \cdot (I - E) - g(t). \end{aligned} \tag{3}$$

where $p = C/(C + FM)$ corresponds to a ratio established by Forbes [1] where $C = 10.4\ \hat{\rho}_{FFM}/\rho_{FM}$. The parameters ρ_{FM} and $\hat{\rho}_{FFM}$ correspond to the constants $\rho_{FM} = 9.4$ kcal/g ($= 9400$ kcal/kg) and $\hat{\rho}_{FFM} = (4.3 \cdot FFM + 837)$ kcal/kg, where FFM represents the reference fat free mass (kg) data.
For system (3), to account for the **growth term** ($g(t)$) we used the function:

$$g(t) = A \cdot e^{-(t-t_A)/\tau_A} + B \cdot e^{-(t-t_B)^2/2\tau_B^2} + D \cdot e^{-(t-t_D)^2/2\tau_D^2}, \tag{4}$$

where the specific parameters for males and females are shown in Table 1.[1, 2].

Table 1: **Parameters for the growth function g as established in (4) from [1, 2].**

Parameter	Males	Females	Scale
A	3.2	2.3	kcal/day
B	9.6	8.4	kcal/day
D	10.1	1.1	kcal/day
τ_A	2.5	1	years
τ_B	1	0.9	years
τ_D	1.5	0.7	years
t_A	4.7	4.5	years
t_B	12.5	11.7	years
t_D	15	16.2	years

The **Energy expenditure rate** (E) in (3) is given by:

$$E = K + \gamma_{FFM} FFM + \gamma_{FM} FM + \beta \Delta I + \delta \cdot BW + \eta_{FFM} \cdot \frac{dFFM}{dt} + \eta_{FM} \cdot \frac{dFM}{dt}, \quad (5)$$

where K represents an energy expenditure constant dependent on the indivudal's gender but irrespective of age ($K = 800$ kcal/d for males; $K = 700$ kcal/d for females); $\beta = 0.24$ stands for the adaptation of energy expenditure when energy intake is perturbed ΔI; $\eta_{FM} = 180$ kcal/kg and $\eta_{FFM} = 230$ kcal/kg account for "biochemical efficiencies associated to fat and protein synthesis"[1].

The function for **physical activity** (δ) in (5) is given by:

$$\delta(t) = \delta_{min} + \frac{(\delta_{max} - \delta_{min}) P^h}{t^h + P^h}. \quad (6)$$

The minimum physical activity for all ages and genders is represented by the constant $\delta_{min} = 10$ kcal/kg/d. The constant for maximum physical activity is gender specific and given by $\delta_{max} = 19$ kcal/kg/d for males and $\delta_{max} = 17$ kcal/kg/d for females.

The parameter $P = 12$ years represents the point of maximum physical activity whilst the constant $h = 10$ represents the rate of decline as a function of age.

The **perturbation of energy intake** ΔI in (5) represents the shift away from the energy intake associated with normal growth. Within this work, we have assumed an energy intake rate $I(t)$ equal to the reference energy intake rate $I_{ref}(t)$ described in (7). I_{ref} represents the **reference energy intake** for normal growth:

$$\begin{aligned} I_{ref}(t) = EB_{ref} + K + (\gamma_{FFM} + \delta) FFM_{ref} + (\gamma_{FM} + \delta) FM_{ref} + \frac{\eta_{FFM}}{\rho_{FFM}} (p \cdot EB_{ref} + g) \\ + \frac{\eta_{FM}}{\rho_{FM}} \big((1 - p) \cdot EB_{ref} - g \big). \end{aligned} \quad (7)$$

Thus the ΔI term in equation 5 equals 0.

The **energy balance of reference** (EB_{ref}) used in equation 7 was adapted from Katan et al.[2] and is given by:

$$EB_{ref}(t) = A_{EB} \cdot e^{-(t - t_A^{EB})/\tau_A^{EB}} + B_{EB} \cdot e^{-(t - t_B^{EB})^2 / 2(\tau_B^{EB})^2} + D_{EB} \cdot e^{-(t - t_D^{EB})^2 / 2(\tau_D^{EB})^2}. \quad (8)$$

The gender specific parameters for this function are shown in Table 2.

Table 2: **Parameters for the energy balance function EB_{ref} as established in** (8) **from Katan et al., [2].**

Parameter	**Males**	**Females**
A_{EB}	7.2	16.5
B_{EB}	30	47
D_{EB}	21	41
τ_A^{EB}	15	7
τ_B^{EB}	1.5	1
τ_D^{EB}	2	1.5
t_A^{EB}	5.6	4.8
t_B^{EB}	9.8	9.1
t_D^{EB}	15	13.5

Finally with the combination of the above equations, the closed form expression for the **energy expenditure rate** equation (5) is given by:

$$\mathrm{E} = \frac{K + (\gamma_{FFM}+\delta)FFM + (\gamma_{FM}+\delta)FM + \beta\cdot\Delta I + \left(\frac{\eta_{FFM}}{\hat{\rho}_{FFM}}p + \frac{\eta_{FM}}{\rho_{FM}}\cdot(1-p)\right)\cdot I + g\cdot\left(\frac{\eta_{FFM}}{\hat{\rho}_{FFM}} - \frac{\eta_{FM}}{\rho_{FM}}\right)}{1 + \frac{\eta_{FFM}}{\hat{\rho}_{FFM}}p + \frac{\eta_{FM}}{\rho_{FM}}\cdot(1-p)}. \tag{9}$$

1.1 Initial values of fat mass and fat free mass for the system of ordinary differential equations

We estimated the **initial fat mass** (FM_0) used in the system (3) utilizing the equations presented by Deurenberg et al.[3]:

$$FM_0 = \begin{cases} \frac{1.51\cdot\mathrm{BMI}_0 - 0.7\cdot a - 2.2}{100}\cdot BW_0, & \text{if Male} \\ \\ \frac{1.51\cdot\mathrm{BMI}_0 - 0.7\cdot a + 1.4}{100}\cdot BW_0, & \text{if Female} \end{cases} \tag{10}$$

where a represents the individual's age in years, BMI_0 the initial body mass index (kg/m^2) and BW_0 the initial body weight.

The **initial fat free mass** (FFM_0), for that same system, is given by the difference between initial fat mass and initial body weight:

$$FFM_0 = BW_0 - FM_0. \tag{11}$$

1.2 Reference body composition data

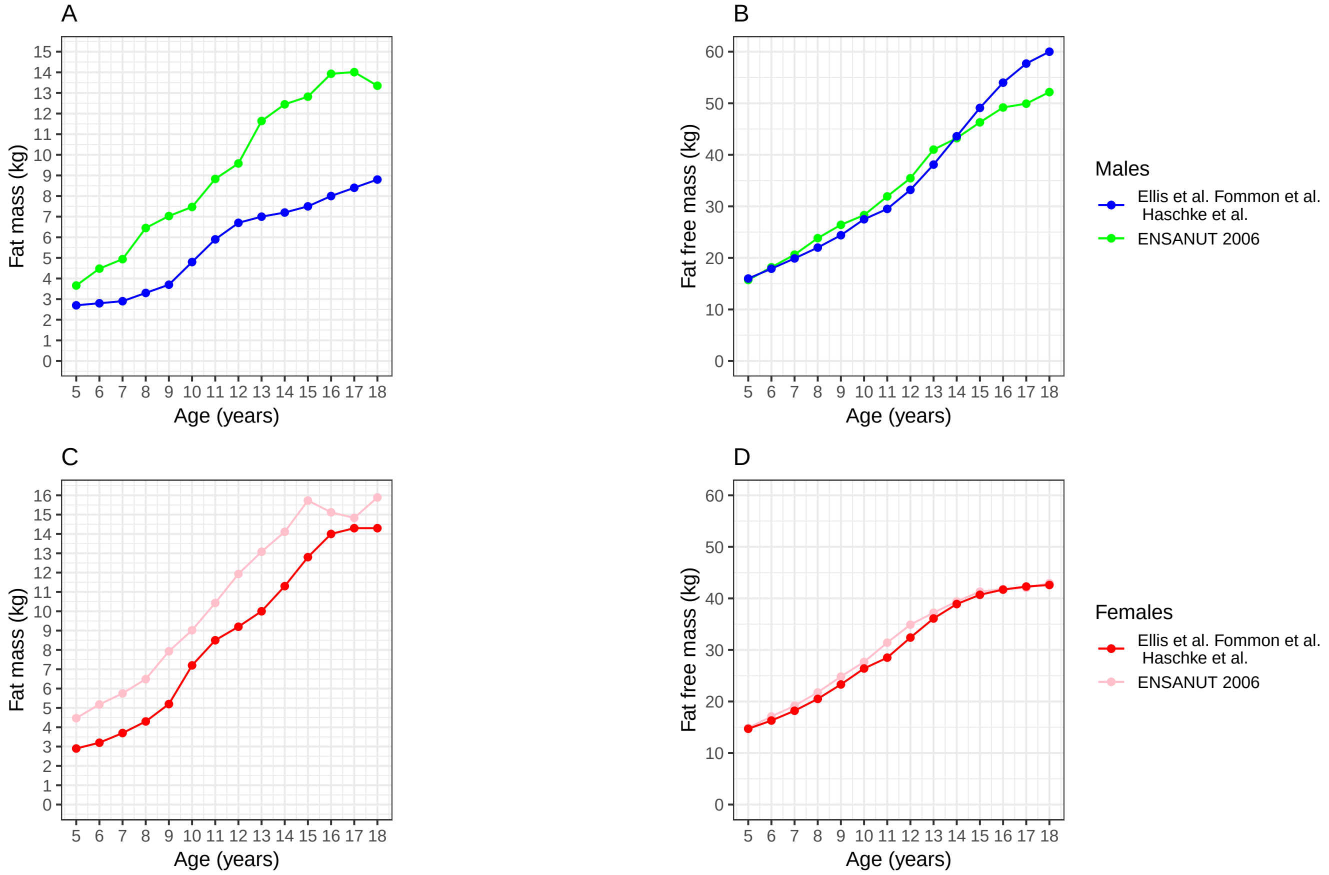
We use data from ENSANUT 2006 to derive reference fat free mass (FFM_{ref}) and reference fat mass (FM_{ref}) values by age and gender for the Mexican population, as shown in Table 3. These were used in the equation (7) for the reference of energy intake term (EB_{ref}) as linear interpolations.

Table 3: **Reference values of fat mass and fat free mass (kg) from ENSANUT 2006** [4]

	Males		**Females**	
Age	Fat Free Mass (kg)	Fat Mass (kg)	Fat Free Mass (kg)	Fat Mass (kg)
5	15.72	3.66	14.86	4.47
6	18.18	4.48	17.09	5.18
7	20.63	4.94	19.16	5.75
8	23.83	6.45	21.75	6.49
9	26.42	7.03	24.83	7.93
10	28.30	7.47	27.67	9.02
11	31.93	8.83	31.41	10.43
12	35.46	9.58	34.90	11.93
13	41.01	11.64	37.22	13.08
14	43.23	12.45	39.41	14.11
15	46.30	12.82	41.30	15.73
16	49.18	13.93	41.80	15.12
17	49.92	14.01	42.05	14.83
18	52.17	13.35	42.96	15.89

Figure 1, shows the difference between the reference FM and FFM data used to calibrate the original DCGO model[5, 6, 7] versus the corresponding values used for the Mexican population. The Mexican data were composed by individuals aged 5 to 18 years from ENSANUT 2006 [4]. We used these reference values to re-calibrate the model and adapt it to the Mexican population.

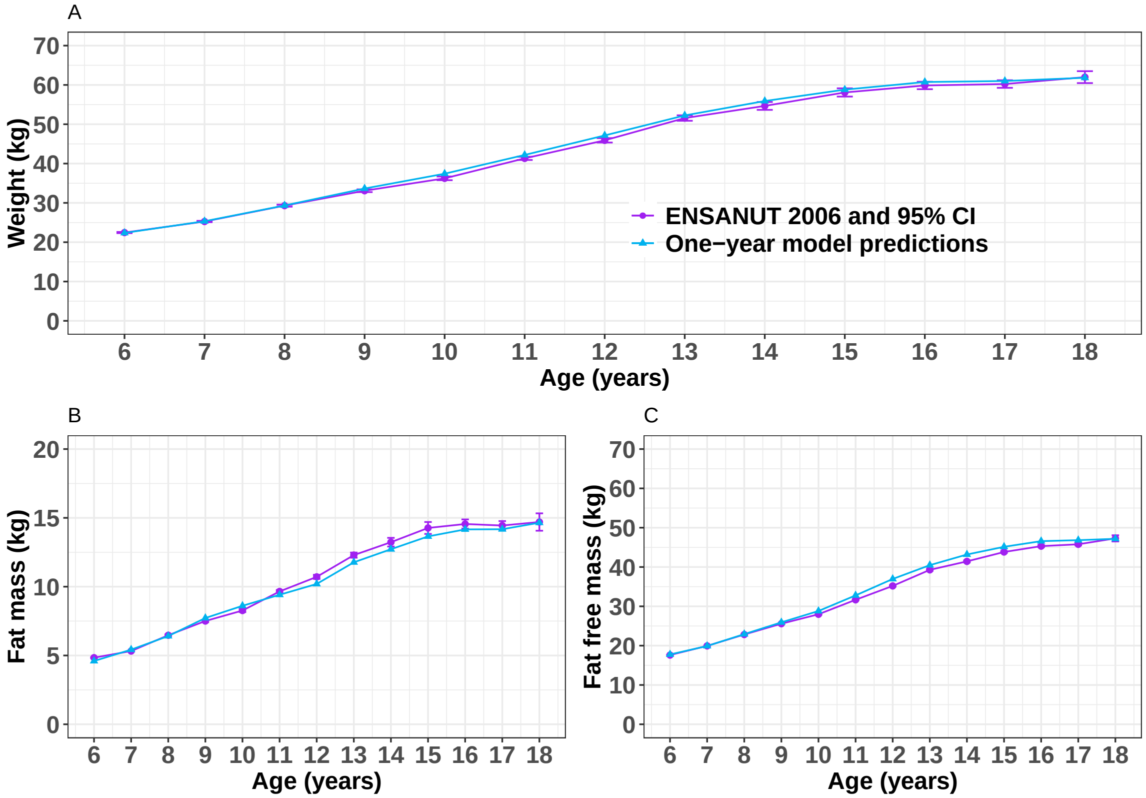
Figure 1: **Comparison between the body composition references [5] [6] [7] used for the DCGO model and [4] for Mexican population, by gender.**



1.3 Model re-calibration and validation

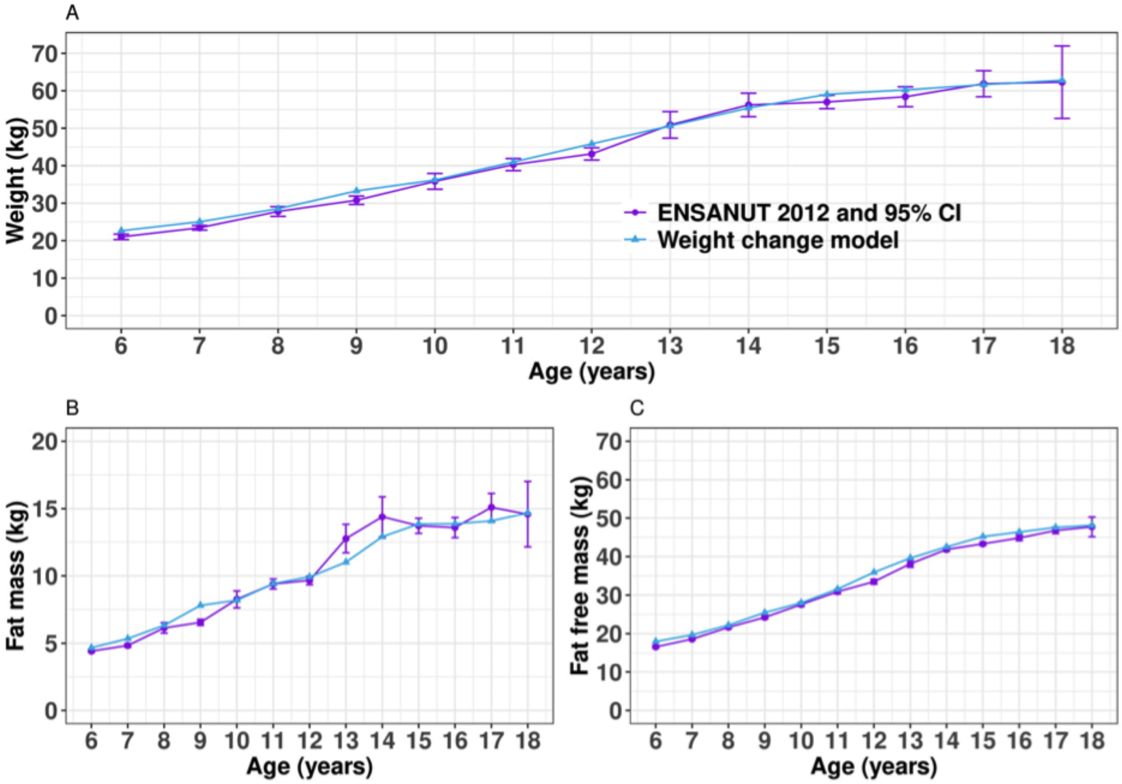
The original DCGO model was re-calibrated to reference body composition data from Mexican children as explained in Section 1.2. A comparison between the one-year simulated weights for children 5-17y (FM and FFM) from ENSANUT 2006 obtained with the DCGO model, and the observed average body weight for children ages 6-18 from ENSANUT 2006, showed an average error of 0.65 kg in weight (Figure 2).

Figure 2: **Comparison of average body composition data between the DCGO model one-year predictions of ENSANUT 2006 [4] children aged 5-17 and ENSANUT 2006 [4] reported average values. Weight (A), fat mass (B) and fat free mass (C).**



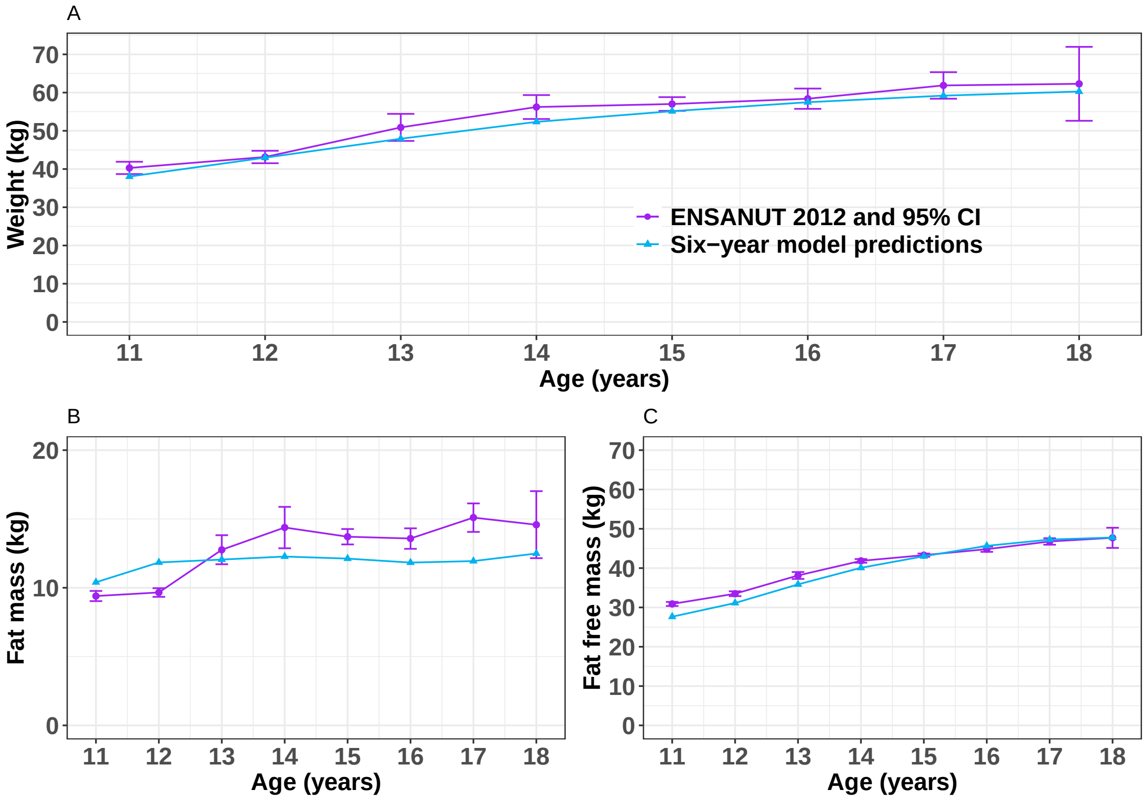
For validation purposes, we compared the mean body weights, FFM and FM by age (ages 6-18) from ENSANUT 2012 with the average one-year simulated weights from our weight model, using data from ENSANUT 2012 children ages 5-17. One-year predictions were consistent with the observed average weights for the corresponding ages in the ENSANUT 2012 data, with a 1.22 kg error (Figure 3).

Figure 3: **Reported (ENSANUT 2012) and model-simulated one-year average body weight (A), fat mass (B) and fat free mass (C) by age**



As an additional validation, we used the model and data from ENSANUT 2006 for children aged 5-12 to predict the average weight after 6-years (ages 11-18), to compare these predictions with the observed ENSANUT 2012 average weights, FM and FFM for ages 11-18. The 6-year predictions based on 2006 data were consistent with the observed average values in ENSANUT 2012, with an error of 2.10 kg in weight ($< 5\%$), 1.03 kg ($< 11\%$) in fat mass and 1.07 ($< 4\%$) in fat free mass (Figure 4).

Figure 4: **Comparison of average body composition data between the DCGO model six-year predictions with ENSANUT 2006 [4] children aged 5-12 and ENSANUT 2012 [8] reported average values. Weight (A), fat mass (B) and fat free mass (C).**



2 Sugar sweetened beverages consumption

We derived sugar sweetened beverages (SSB) consumption and total energy intake (TEI), using data from ENSANUT's 2012, 7-day semi-quantitative FFQ [9]. The individual amount of kcal/day from SSB was estimated as a fixed proportion of the reported TEI. This proportion was calculated for each individual k as:

$$propSSB_k = \frac{Reported\ SSB\ intake\ (k)}{Total\ energy\ intake\ (k)}. \tag{12}$$

The implementation of a 10% tax scenario yields to a purchase reduction of 0.4% in low and 13.2% in high SSB purchasers, respectively [10]. Based on this result we assumed the same reductions in SSB consumption. Applying a linear behavior, a tax of 20% would reduce $2 \cdot 0.4\%$ or $2 \cdot 13.2\%$ depending on the SSB consumption level and so on. We estimated the change in SSB energy intake attributable to taxation as follows:

$$\Delta SSB_k^{tax}(t) = 1 - propSSB_k(t) \cdot reduction^{\text{tax}}. \tag{13}$$

Finally, we estimated the new energy intake rate for each individual (i) using different taxes as:

$$\Delta I_{(k,ref)}^{\text{tax}}(t) = \big(I_{(k,ref)}(t) \cdot \Delta SSB_k^{\text{tax}}(t)\big). \tag{14}$$

2.1 Body weight estimation under baseline and taxed SSB scenarios

First we obtained the energy intake for every individual k in ENSANUT 2012 at time t as described in Section 1. Then we calculated the predicted weight $BW^{(k)}(t)$ using the weight change model:

$$BW_k^{\text{baseline}}(t) = BW_k^{\text{model}}\big(t + age_k;\ \text{Sex}_k, FM_k, FFM_k, I_{(k,\text{ref})}(t)\big). \tag{15}$$

To obtain the corresponding predicted weight under different SSB tax scenarios, the input for energy intake was considered as in equation (14), the new body weight was computed using:

$$BW_k^{\text{tax}}(t) = BW_k^{\text{model}}\big(t + age_k;\ \text{Sex}_k, FM_k, FFM_k, \Delta I_{(k,ref)}^{\text{tax}}(t)\big). \tag{16}$$

For our final outcome, we estimated each individual's body weight difference between no tax and different tax scenarios as:

$$\Delta BW_k^{\text{tax}}(t) = BW_k^{\text{baseline}}(t) - BW_k^{\text{tax}}(t). \tag{17}$$

3 Sensitivity analysis

We constructed a consumption-percent change Matrix Λ. This matrix, contains different combinations of taxation and caloric compensation scenarios, ranging from 0% to 100% by 10%. (Table 4). Each entry $\lambda_{i,j}$, corresponds to the percent of SSB reduction associated to different tax and compensation values and is calculated as follows:

$$\lambda_{i,j} = (i-1) \cdot \left(1 - \frac{(j-1)}{10}\right), \tag{18}$$

where $i = \{0\%, 10\%, 20\%, 30\%, \ldots, 100\%\}$, represents the tax values and $j = \{0\%, 10\%, 20\%, 30\%, , \ldots, 100\%\}$ the compensation values. Then, each entry $\lambda_{i,j}$ will be multiplied by the corresponding reduction for each individual's level of consumption.

Table 4: **Matrix Λ with percent reductions in SSB consumption, corresponding to tax and compensation augmentation.**

		% Compensation										
		0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
% Tax	**0**	0	0	0	0	0	0	0	0	0	0	0
	10	10	9	8	7	6	5	4	3	2	1	0
	20	20	18	16	14	12	10	8	6	4	2	0
	30	30	27	24	21	18	15	12	9	6	3	0
	40	40	36	32	28	24	20	16	12	8	4	0
	50	50	45	40	35	30	25	20	15	10	5	0
	60	60	54	48	42	36	30	24	18	12	6	0
	70	70	63	56	49	42	35	28	21	14	7	0
	80	80	72	64	56	48	40	32	24	16	8	0
	90	90	81	72	63	54	45	36	27	18	9	0
	100	100	90	80	70	60	50	40	30	20	10	0

Using Matrix Λ, we calculated the change in SSB energy intake attributable to taxation as follows:

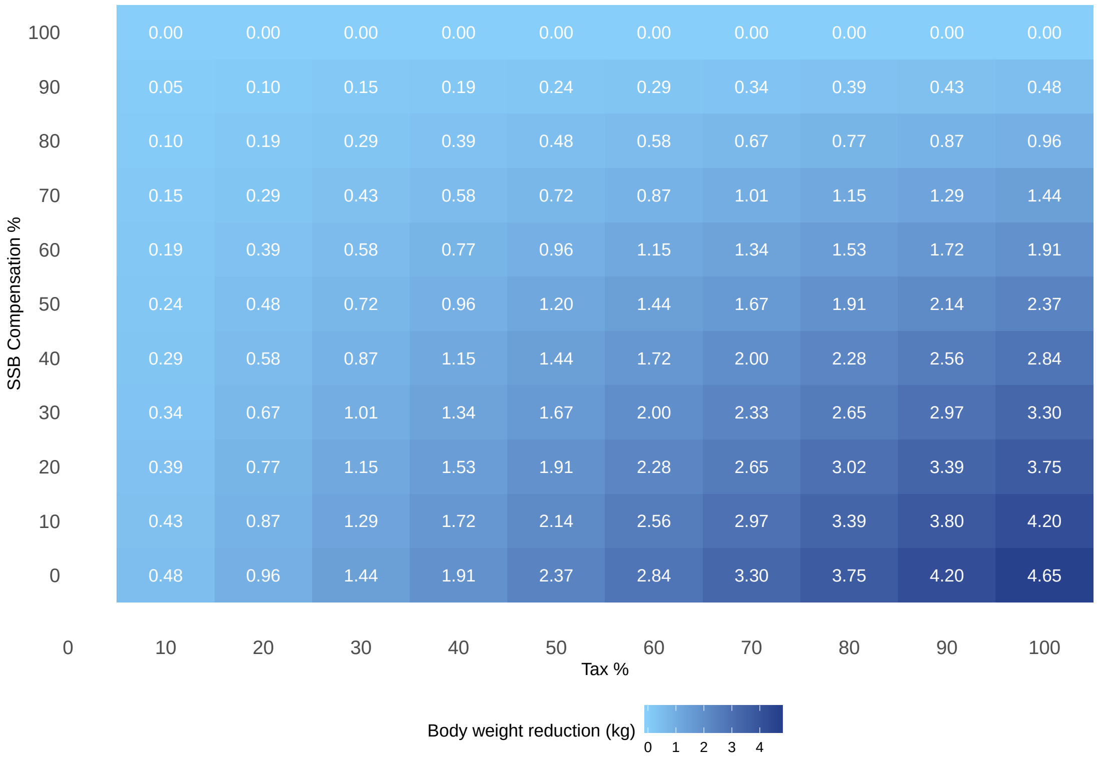
$$\Delta SSB^{k}_{(i,j)}(t) = 1 - propSSB_k(t) \cdot \lambda_{i,j}, \tag{19}$$

The new energy intake was estimated as in equation (14) and applied to the individual weight change model. Then, we estimated the values of the average body weight differences calculated as in section 2.1.

3.1 Long-term weight impact of the SSB-tax

As additional sensitivity analysis, we projected the potential long-term effect on weight of the implementation of the SSB tax. Figure 5 shows the results of our sensitivity analysis after 3 years of SSBs tax implementation. Overall, we observe that the potential effect of different tax and compensation scenarios on weight reduction could range between -0.48 kg with a 10% tax up to -4.65 kg with a 100% tax assuming a 0% caloric compensation. Nonetheless, even with a high caloric compensation (90%), we could still obtain weight reductions ranging from -0.05 kg to -0.48 kg with 10% or 100% taxes, respectively.

Figure 5: **Sensitivity analysis for estimated weight (Kg) change after 3 years based on different sugar reductions and compensation rates.**



	10	20	30	40	50	60	70	80	90	100
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.05	0.10	0.15	0.19	0.24	0.29	0.34	0.39	0.43	0.48
80	0.10	0.19	0.29	0.39	0.48	0.58	0.67	0.77	0.87	0.96
70	0.15	0.29	0.43	0.58	0.72	0.87	1.01	1.15	1.29	1.44
60	0.19	0.39	0.58	0.77	0.96	1.15	1.34	1.53	1.72	1.91
50	0.24	0.48	0.72	0.96	1.20	1.44	1.67	1.91	2.14	2.37
40	0.29	0.58	0.87	1.15	1.44	1.72	2.00	2.28	2.56	2.84
30	0.34	0.67	1.01	1.34	1.67	2.00	2.33	2.65	2.97	3.30
20	0.39	0.77	1.15	1.53	1.91	2.28	2.65	3.02	3.39	3.75
10	0.43	0.87	1.29	1.72	2.14	2.56	2.97	3.39	3.80	4.20
0	0.48	0.96	1.44	1.91	2.37	2.84	3.30	3.75	4.20	4.65

4 Model Inputs

Input	Description	Value	Reference
Age	Age in years	5-18	ENSANUT 2012 [8]
Sex	male or female	0/1	ENSANUT 2012 [8]
Height	Height in meters	0.9-1.90 m	ENSANUT 2012 [8]
BW_0	Initial Body Weight	12-140 kg	ENSANUT 2012 [8]
BMI	Body mass index	10-58 $\frac{kg}{m^2}$	ENSANUT 2012 [8]
FM_0	Initial fatmass	$\frac{(1.51 \cdot BMI - 0.7 \cdot age - 3.6 \cdot sex + 1.4) \cdot BW}{100}$	ENSANUT 2012 [8]
FFM_0	Initial fat free mass	$BW - FM$	ENSANUT 2012 [8]
$\hat{\rho}_{FFM}$	Effective FFM energy density	$4.3(\frac{kcal}{kg^2})FFM(kg) + 837\frac{kcal}{kg}$	Model parameter from Hall et al. [1]
ρ_{FM}	FM energy density	$9.4\frac{kcal}{g}$	Model parameter from Hall et al. [1]
C	Forbes body composition	10.4kg$(\frac{\hat{\rho}_{FFM}}{\rho_{FM}})$	Model parameter from Hall et al. [1]
p	p-radio Energy partitioning	$\frac{C}{C+FM}$	Model parameter from Hall et al. [1]
K	Expenditure constant	male: 800 $\frac{kcal}{d}$ female: 700 $\frac{kcal}{d}$	Model parameter from Hall et al. [1]
η_{FM}	Cost of fat synthesis	180 $\frac{kcal}{d}$	Model parameter from Hall et al. [1]
η_{FFM}	Cost of fat free tissue synthesis	230 $\frac{kcal}{d}$	Model parameter from Hall et al. [1]
β	Adaptive thermogenesis	0.24	Model parameter from Hall et al. [1]
γ_{FM}	Metabolic rate of adipose tissue	4.5 kcal/kg/d	Model parameter from Hall et al. [1]
γ_{FFM}	Metabolic rate of fat-free tissue	22.4 kcal/kg/d	Model parameter from Hall et al. [1]
δ_{min}	Minimum physical activity	10 kcal/kg/d	Model parameter from Hall et al. [1]
δ_{max}	Maximum physical activity	male: 19 kcal/kg/d female: 17 kcal/kg/d	Model parameter from Hall et al. [1]
P	Time of half max. physical activity	12 years	Model parameter from Hall et al. [1]
h	Physical activity Hill coefficient	10	Model parameter from Hall et al. [1]

5 Algorithm and Implementation

To solve the system of differential equations (3), we used a 4th order Runge-Kutta algorithm (RK4)[11] with a stepsize $\Delta t = 1$. This weight model was implemented in the `bw` package in `R` using `Rcpp`[12, 13, 14, 15, 16]. The algorithm 1 contains the pseudo-code of the implementation.

Algorithm 1 Individual level weight change model

```
procedure Weight change model
Input:
    $n$                                ▷ Number of individuals in sample
    Years                              ▷ Number of years to run the model for
    $w_k$                              ▷ Survey weight for $k$-th individual ($k = 1, \dots, n$)
    $I_{ref}^{(i)}(t)^{(k)}$           ▷ $k$-th individual's total energy intake reference
                                         ($k = 1, \dots, n$, $0 \leq t \leq$ Years)
    $\Delta SSB^{(k,\text{tax})}(t)$ ▷ $k$-th individual's energy intake reduction ($k = 1, \dots, n$, $0 \leq t \leq$ Years)
    $BW_{\text{init}}^{(k)}$           ▷ $k$-th individual's reported body weight ($k = 1, \dots, n$)
    $H_{\text{init}}^{(k)}$            ▷ $k$-th individual's reported height ($k = 1, \dots, n$)
    $\text{Age}_{\text{init}}^{(k)}$   ▷ $k$-th individual's reported age ($k = 1, \dots, n$)
    $\text{Sex}^{(k)}$                 ▷ $k$-th individual's sex ($k = 1, \dots, n$)
    for $k$ in 1 to $n$ do
        $\text{BMI}_{\text{init}}^{(k)} \leftarrow BW_{\text{init}}^{(k)} / \left(H_{\text{init}}^{(k)}\right)^2$
        $\text{Body Fat }\%_{\text{init}}^{(k)} \leftarrow 1.51 \cdot \text{BMI}^{(k)} - 0.70 \cdot \text{Age}_{\text{init}}^{(k)} - 3.6 \cdot \mathbb{I}_{\text{Sex}^{(k)} == \text{`Male'}} + 1.4.$
        $FM_{\text{init}}^{(k)} \leftarrow \left(\text{Body Fat }\%_{\text{init}}^{(k)}\right) \cdot BW_{\text{init}}^{(k)}$
        $FFM_{\text{init}}^{(k)} \leftarrow BW_{\text{init}}^{(k)} - FM_{init}^{(k)}$
        $\Delta I(t)_{ref}^{(k,\text{tax})} \leftarrow \left(I_{ref}^{(k)}(t) \cdot \Delta SSB^{(k,\text{tax})}(t)\right).$
        for tax in $[0, 10, 20, 30, 40]$ do
            Runge Kutta 4 do
                Calculate $\hat{\rho}_{FFM}^{(k)}$ and $p^{(k)}$ from (3).
                Calculate $g^{(k)}(t)$ from (4).
                Interpolate linearly the values of Table 3 to calculate $I_{ref}^{(k)}$ as in (7).
                Calculate $E^{(k,\text{tax})}(t)$ from (5).
                Aproximate $\frac{dFFM}{dt}^{(k,\text{tax})}$ and $\frac{dFM}{dt}^{(k,\text{tax})}$ as in (3).
            end Runge Kutta 4
            Calculate $BW^{(k,\text{tax})}(t) \leftarrow FM^{(k,\text{tax})}(t) + FFM^{(k,\text{tax})}(t)$.
            $\Delta BW^{(k,\text{tax})} \leftarrow BW^{(k,0)}(365 \cdot \text{Years}) - BW^{(k,\text{tax})}(365 \cdot \text{Years})$
        end for
    end for
    for tax in [10, 20, 30, 40] do
        for cat in [Males, Females, Overall] do
            $\overline{\Delta BW}_{\text{cat}}^{(\text{tax})} = \sum_{i=1}^{n} w_i \cdot \Delta BW^{(i,\text{tax})} \cdot \mathbb{I}_{\text{cat}}$
        end for
    end for
end procedure
```

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Title: Body weight impact of the sugar sweetened beverages tax in Mexican children: a modeling study.

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