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Africa's oesophageal cancer corridor - do hot beverages contribute?

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Abstract

Purpose—Hot beverage consumption has been linked to oesophageal squamous cell cancer (EC) but its contribution to the poorly-understood East African EC corridor is not known.

Methods—In a cross-sectional study of general-population residents in Kilimanjaro, North Tanzania, tea drinking temperatures and times were measured. Using linear regression models, we compared drinking temperatures to those in previous studies, by socio-demographic factors and tea type ("milky tea" which can be 50% or more milk and water boiled together vs "black tea" which has no milk).

Results—Participants started drinking at a mean of 70.6°C (standard deviation 3.9, n=188), which exceeds that in all previous studies ($p \leq 0.01$ for each). Tea type, gender and age were associated with drinking temperatures. After mutual adjustment for each other, milky tea drinkers drank their tea 1.9°C (95% confidence interval: 0.9, 2.9) hotter than drinkers of black tea, largely because black tea cooled twice as fast as milky tea. Men commenced drinking tea 0.9°C (−0.2, 2.1) hotter than women did, and finished their cups 30 (−9, 69) seconds faster. 70% and 39% of milky and black tea drinkers, respectively, reported a history of tongue burning.

Conclusions—Hot tea consumption, especially milky tea, may be an important and modifiable risk factor for EC in Tanzania. The contribution of this habit to EC risk needs to be evaluated in this setting, jointly with that of the many risk factors acting synergistically in this multi-factorial disease.

Keywords

oesophageal cancer; Tanzania; hot beverages; tea

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Introduction

Oesophageal cancer is a devastating disease that continues to have less than 10% five-year survival despite advances in multimodality therapy [1,2]. It is the sixth most common cause of cancer-related deaths worldwide (400,000 in 2012) [3] and its major histological subtype of oesophageal squamous cell carcinoma (ESCC) comprises 87% of cases [4]. ESCC disproportionately affects discrete areas of Asia, Africa and South America. The African ESCC corridor includes Malawi, Kenya, Uganda, Tanzania and parts of South Africa, but its aetiology is not well understood [5]. In addition to alcohol and tobacco, [6,7] potential contributors to the burden include polycyclic aromatic hydrocarbons, nitrosamines, dietary deficiencies, and, under investigation here, hot beverage drinking [8]. The Kilimanjaro region of North Tanzania has high rates of ESCC today and indeed since the 1970s, [9,10] where the disease is known locally as *kansa ya koo*, literally throat cancer in Kiswahili. In order to elucidate whether hot beverage drinking is a possible contributor to this setting's burden, we measured population-level hot beverage drinking habits.

The strongest evidence linking hot beverage consumption to ESCC comes from the high risk area of the Golestan province of Iran, where Islami *et al.* found 2.1 and 8.2-fold increased ESCC risks for drinkers of hot (approximate temperatures 65–69°C) and very hot (≥70°C) tea respectively, compared to those who drink warm tea (<65°C) [11]. A systematic review confirmed these results across populations worldwide (China, Ethiopia, Brazil, Uruguay), with increased risks shown for hot tea, hot coffee and hot maté drinking, with the latter having been classified by IARC in 1991 as probably carcinogenic to humans [12]. ESCC risks increased according to the beverage's temperature [13,14].

In Tanzania's Kilimanjaro region, although coffee (*kahawa*) is grown, tea from elsewhere in Tanzania or from Kenya, is more commonly consumed. In the domestic setting, it is mainly consumed as either "milky" tea, black tea or as spice tea (*chai masala*). Literature on customs and cultures [15], complemented by local investigators' knowledge, indicate that the local method and composition of milky tea preparation may result in high temperatures at consumption. Notably, cold milk is rarely added after tea preparation. Instead in the preparation of milky tea, water and fresh cow's milk (often over 50% milk) are boiled together on a wood fire (as in Supplementary Figure 1A). Tea leaves and sugar (almost always added in this setting) are then added to boil further and the prepared tea is then stored in a thermal flask, until pouring into cups for consumption. If an individual desires even more sugar, they can add extra into their individual cup after the tea has been poured. In rural areas, electricity or generators are scarce so refrigerated pasteurized milk is not available in the home. Tea is often consumed at breakfast, and in the rainy season it serves to warm the body on cooler mornings especially at higher altitudes (900–2000m).

A quantitative study of hot beverage drinking has not, to our knowledge, been published for Tanzania. To shed light on ESCC epidemiology in this setting, here we report findings of the first cross-sectional study of reported and measured hot beverage consumption in the Kilimanjaro general population.

Materials and Methods

Study design and setting

We conducted a cross-sectional study of established and putative ESCC risk factors in the sub-divisions of Lyamungo, Masama and Machame, Hai district, Kilimanjaro region (latitude S 3°12′41, longitude E 37°E13′21, altitude 1200–1600m, Supplementary Figure 2). The location was chosen because it was the residential origin of an overrepresentation of EC patients diagnosed at the tertiary Kilimanjaro Christian Medical Centre (KCMC) in the region's capital town of Moshi (unpublished data). The sampling strategy utilised in the 3 subdivisions was the same. In each subdivision, from a list of its wards, 5 were randomly chosen, and from each ward 4 villages/hamlets were randomly chosen, giving a total of 60 villages represented. In each village, fieldworkers approached one or two households near accessible roads, until they reached 100 households in total. This is a rural community in which people work at home on the farm for their daily livelihood, thus we noted only 1 household refused to participate. At each house, two adult members (≥18 years) were invited to participate in the study – this paired design was implemented to examine within *versus* between household correlation in urinary micronutrients (not reported here). The study involved an in-person interview, providing a urine sample (not used in the present study) and having beverage temperature measured whilst drinking a hot beverage. All interactions took place at the participant's home between 26 January and 24 February 2014, which is during the dry season when average daily minimum and maximum ambient temperatures are 12 and 30°C respectively [16]. The questionnaire, administered in Kiswahili, included socio-demographic factors, tobacco, alcohol, and usual hot beverage drinking habits: type (tea/coffee, with/without hot or cold milk), type of milk (fresh cow's/carton), frequency of consumption by time of day and season, frequency of tongue burning and how hot (very hot, hot, warm, and cool) and fast they drink compared to others.

Hot beverage measurement

Fieldworkers were trained to administer a hot beverage measurement protocol which attempted to reproduce that used in Golestan.[11] They asked participants to prepare, pour and drink a hot beverage in the normal manner. All participants chose to make tea. Tea preparation, and drinking, usually occurs outside in external kitchens/eating areas. Two cups were poured simultaneously into 2 identical cups, one for consumption and one for temperature measurement. The cups were provided by the participants so as to mimic usual habits and were often china 200 ml cups, though we did not record the exact cup material, volume or volume of liquid drank. A digital thermometer (HANNA instruments®, Woonsocket, RI, US) was placed in the fieldworker's cup, and the temperature was immediately recorded at pouring, when a stop watch was started (see Supplementary Figure 1B). When the temperature reached 75°C the participant was asked to sip their tea and say whether it was how hot they usually drink. This was repeated at 70°C and every 5°C until they reached their desired drinking temperature, when the time and temperature were recorded. These measurements were also noted when half of and all of the cup were drank. We noted whether milk was added before or after boiling, however as sugar is almost always added in this setting, its addition in the tea preparation or further addition by the individual was not noted.

Comparisons

For comparative purposes, we searched the literature for reports of measured hot beverage temperatures in other settings, for which we extracted the mean, no. participants and standard deviations (SD) of temperatures at first sip. We found studies from the US, UK, and in high-EC risk areas of Brazil and Iran (for Iran, the mean was calculated using a frequency-weighted average of the midpoint of categories).[11,17–19]

Ethical approval

This study was approved by the KCMC Institutional Review board (Amendment 13 November 2013) and the IARC ethics committee (Ref: IEC 14–15).

Statistical Analysis

Four sets of times and temperatures (time in minutes and seconds, temperature in °C) were recorded: at pouring (0, T_p), at first sip (t_0, T_0), at half cup (t_h, T_h) and at the end of drinking the full cup (t_f, T_f). The time from first sip to end of cup was calculated as $t_f - t_0$. Applying Newton's law of cooling and assuming a constant cooling rate per cup and an ambient temperature of 20°C, the average drinking temperature (T_A) across the cup was calculated as $T_A = 20 + (T_0 - T_f)(\ln((T_0 - 20)/(T_f - 20))]$. Temperatures and times were plotted using smoothed density plots, and a Student's t-test was used to compare mean T_0 in Tanzania to international means. Normal error regression models were used to examine associations with tea drinking temperatures and with drinking times. Univariate models were first fitted, and thereafter multivariate models adjusted for gender and age. Age was fitted as a linear term, as there was no evidence of non-linearity for age (p=0.85 for quadratic term for age), as was number of appliances (p=0.43). Agreements of categories of measured and reported temperatures were assessed using weighted kappa statistics.

To assess how much longer one should wait after pouring at a median temperature of 79°C (denoted by t_{msp}=minutes since pouring) for tea to cool to 60°C, we plotted the cooling curve using Newton's law ($T(t_{msp}) = T_A + (79 - T_A)e^{-k.tmsp}$), where T_A is the ambient temperature assumed to be 20°C and k was the observed median cooling constant for milky and black tea respectively (k=0.035 and 0.072). Times since pouring to reach 60°C were calculated as (1/k).ln(59/40). Analyses were carried out using STATA version 12.0 (College Station, Texas, US).

RESULTS

A total of 188 adults (83 male, 105 female) participated, consisting of 91 household pairs and 6 individuals who were home alone at the time of visiting. There was one refusal due to scheduling conflicts. 75% of interviews took place between 10 am and 2 pm. The socio-demographic characteristics of participants are shown in Table 1. Mean age was 52.7 years (SD 17.1, range 18–98) and women were younger than men (means of 49.7 and 56.4 years). The majority of participants were from the Chagga ethnic group. Three-quarters had at most primary school education and were farmers or worked in the home. 79% had piped water, 98% used wood fires for cooking, but refrigerators and electric kettles were less common (~7%).

In tea preparation, 62% of participants added milk before boiling (i.e. milky tea) and 37% did not add milk (i.e. black tea) (Table 2). Tea was poured into cups at a mean temperature of 78.3°C (SD 3.9, range 65–86) and was first drunk 1.9 (SD 1.3) minutes later at 70.6°C (SD 3.9, range 57–79). The proportion who started drinking their tea at <65, 65–69 and ≥70°C (associated with approximate ESCC relative risks of 1, 2, and 8 respectively from the Iranian study[11]) were 9, 18 and 73%. Mean time to drink the full cup from first sip was 5.0 minutes (SD 1.8), by which time the cup had cooled to 60.2°C. Figures 1A and 1B show the relative frequency distributions of these times and temperatures. The temperature when tea drinking commenced was higher in this study than in all comparative studies, including the US (61.5°C, p<0.001), UK (53.6°C, p<0.001), Brazil (69.5°C, p=0.01) and Iran (62.4°C, p<0.001) (Figure 1C). Notably the mean temperature at the end of the cup (60.2°C) was similar to starting temperatures in the UK and US.

Correlates of drinking temperatures and times are shown in Table 3. The strongest determinant of tea temperature was the type of tea; milky tea was 2.0°C hotter than black tea when poured. Further, despite drinkers spending 1 min 15 seconds longer drinking their tea, the average temperature of milky tea was 1.6°C higher than that of black tea at the end of the cup. This occurred because of a faster rate of cooling of black than of milky tea, which cooled by a median 3.2°C per minute over the drinking temperatures, whereas the milky tea cooled at 1.6°C per minute (raw data are plotted in Supplementary Figure 3).

Younger age and being male were also associated with higher starting temperatures (non-significant) and because these groups also drank faster, they had significantly higher average drinking temperatures. Men were older, thus comparing men to women of the same age who drink the same beverage type, men drank the cup at an average temperature 1.3°C (0.3, 2.3) hotter than women. Older participants drank at slightly lower average temperature (mean temperature reduction per 10 years increase in age: 0.3°C (95% CI 0.0, 0.6), a trend which was present in both women and men (data not shown)).

Reported hot beverage drinking habits agreed with the observed preparation, notably everyone drank tea daily and 60% drank milky tea (Table 2). Milk was fresh cow’s and never carton milk. Drinking habits varied by season. Whilst tea was drunk in the morning throughout the year, 64% of participants additionally drank it on winter and summer evenings and 20% on winter evenings only. Almost all participants (91%) considered their tea as “hot”, thus this question did not provide agreement, above that due to chance, with categories of measured drinking temperatures (*kappa*=0.04). A majority (89%) of participants reported starting to drink hot beverages under age 5 years.

Over half of participants (58.8%) reported having previously burnt their tongue with a hot drink, and amongst those who did, they had burnt it a median of 3 times in the last year (Table 2). Tongue burning was associated with hotter measured temperatures at both the first sip and average over the cup (plotted in Figure 2). Those who had burnt their tongue started drinking at a temperature of 1.7°C (95% CI 0.5, 2.8) higher. 75% of milky tea drinker had burnt their tongue, compared to 39% of drinkers of black tea, but within each tea type, time to first sip was not associated with reported burning (Figure 2). There was no trend seen

between the number of tongue burning times in the last year and tea temperature (data not shown).

The median cooling curves, from a poured temperature at 79°C, for milky and black tea, are shown in Figure 3 and overlaid are the observed temperature interquartile ranges at first and last sip. The median temperature at first sip was 71–72°C for both black and milky tea. Drinkers of milky tea would have to wait a further 6–7 minutes before starting to drink at 60°C, whereas drinkers of the faster-cooling black tea need a further 3 minutes for theirs to reach this temperature.

DISCUSSION

Findings

In this study of measured tea temperature in the Kilimanjaro region of Tanzania, we found that tea drinking commenced piping hot (70 °C at start) and reduced to 60°C during 5 minutes of drinking. This was particularly pronounced in the 60% of participants who drank hot "milky" tea (half or more water and fresh cow's milk boiled together), which cooled at half the rate of black tea, thus although milky tea drinkers spent longer drinking tea, its temperature was over 60°C by the end of the cup at which time it was 3°C higher than in drinkers of black tea. Milky tea drinkers also burnt their tongues more frequently. Independent of tea type, men drank tea 1.0°C hotter than women, as did younger compared to older participants. Starting drinking temperatures exceeded those in all previous international studies [11,18,20]. Most notably, temperatures were higher than in Golestan, Iran, where 2- and 8-fold increases in the risk of ESCC were found for 65–69 and ≥70°C (approximately). 70% of this study's participants *versus* 5% of the Golestan cohort lay in the top temperature category. If thermal injury is causally associated with ESCC risk then this study strongly suggests that hot beverages and particularly hot milky tea may be a contributor to esophageal cancer in this region of Tanzania.

For those who prefer tea with milk, boiling of this unpasteurized fresh cow's milk is encouraged in this setting to render it safe.[21] Thus if ESCC risks are raised through thermal injury from hot beverages, a useful prevention initiative needed in this setting is to wait 10–11 minutes after milky tea is poured from a thermal flask before drinking and 5 minutes for black tea, rather than the current 2 minutes. This prolonged waiting time would represent a simple and free intervention and would still ensure an appealing temperature to the consumer. Note that this differs to Western contexts for which recommendations are often given in terms of waiting times *before* pouring from the teapot [33]., rather than *after* pouring and before drinking. We use the latter here, as it is more common to pour from a thermal flask which is not cooling rapidly, unlike a teapotAdding cold pasteurized milk is not a realistic option at present with refrigerator-ownership are 14% in this region. If refrigerated milk were available, as is the case in more urban areas of Tanzania,[35] replacement of 15% of a 70°C cup by 3°C milk, rapidly reduces the temperature to a safer 60°C, without waiting needed.

Plausibility

In the present study, a somewhat unexpected finding was the extent of the slower rate of cooling of milky than of black tea. These slower cooling rates were likely to be due the fat content of milky tea, which we indeed confirmed in independent cooling curves measured at IARC and in Moshi, where, in order of slowest to fastest cooling, were cream, raw cow's milk, carton milk, then water. Raw cow's milk, most often from the traditional shorthorn zebu cow in the Kilimanjaro setting, typically has a higher butterfat content (4–6%) compared to pasteurized shop-bought carton milk (3–4% for 'whole milk') and indeed has no chance of adulteration to lower butterfat content, as is more prevalent in milk consumed in urban areas. [22] Previous studies have also seen a slower cooling rate of white than of black tea/coffee, despite a lower heat content of the former, and this effect was not explained by a differential radiation effect, but was thought to be due to a lower rate of evaporation in the milky/white tea. [23] The differential composition of milky than of black tea may also be of further significance upon tissue contact as it is likely to have a greater scalding potential. Indeed for dermatologic scald burns, those from hot milk have a greater burn depth and higher fatality rates than those from hot water. [24,25]

It is plausible that repeated thermal injury may be a contributor to the high rates of oesophageal cancer in this setting. Thermal injury to the oesophageal mucosa may be implicated in carcinogenesis, through chronic inflammation and subsequent activation of endogenous nitrogen species. Alternatively, thermal injuries may damage the mucosa's repair mechanisms when other carcinogenic insults are present (e.g. PAHs, alcohol). In mouse models, the quantity and size of oesophageal papillomas increased substantially after hot water was administered to the oesophagus [26], whilst in humans, acute scalding of the oesophagus results in a reversible pseudomembrane which can occur throughout the oesophagus, consistent with non-specific location of ESCC tumours throughout the upper, middle and lower oesophagus. An impaired mucosa may be exposed to other ESCC carcinogens likely to be present in this Tanzanian setting, for example from a high nitrate concentration in drinking water or high ethanol-content home brews (gongo).[27,28] Nonetheless, in the present sample, there was no indication of a clustering of these exposures in drinkers of hotter teas. On the other hand, it should be noted that other or additional mechanisms to thermal injury have been proposed for the increased risks associated with hot infusions – e.g. direct carcinogenic effects of tannins, polycyclic aromatic hydrocarbons or other chemical constituents present or acquired during the beverage preparation [29].

Thermal energy transfer to the oesophagus on swallowing of hot liquids depends not only on the temperature of the liquid, as we observed, but also on the surface area of contact, thickness of the liquid, temperature differential and on the liquid's thermal properties (Fouriers' Law of heat transfer). The latter properties differ between milky and black tea, with milky tea having a slightly lower specific heat capacity (calories needed to heat a unit mass by 1°C,) and lower thermal conductivity (~0.545 *versus* 0.57 W m^{-1} $°C^{-1}$) [30]. Thus, although milky tea has an estimated marginally smaller energy transfer) (by 5%) than black tea if tissue contact was at the same temperature, that effect must be outweighed by the observation that milky tea was several degrees hotter. This latter effect is evidenced in the

much greater proportion of participants who had burnt their tongue amongst the drinkers of milky than of black tea. Future work would benefit from direct measurements of the heat energy in these two different beverage compositions.

Strengths and limitations

This is the first hot beverage prevalence study we know of in this high-ESCC incidence area. It features several strengths, including near 100% participation, its community-based study population, measurements of temperatures of usual drinking habits in the home. However, there is a possibility that temperatures are overestimated if participants commence drinking because of the prompt to test. Whilst this was possible, it should not have affected the high half-cup temperature. Hot temperatures are also consistent with the tongue burning prevalence. The study's sample size was limited and had sufficient power (>90%) to detect mean temperatures differences of 2°C or more (with n=188, split in half, SD 3.9), whereas the power to detect differences of 1.5°C, 1°C and 0.5°C was 75, 42 and 14% respectively. Given that milky tea was very hot and cooled slowly, it would have been useful if we had measured the volume water:milk, liquid volume, size and dimension of the cup and its material. Notably, although milky tea cooled slower, at 1.6°C/min between 70 and 60°C, than black tea, this rate is faster than a full 225ml ceramic mug at 20°C ambient temperature (rate of ~1°C/min). The relatively fast rate of cooling in this setting may reflect a combination of a cool ambient temperatures, ventilation to aid evaporation from the outdoor setting, small volume (thus larger surface area:volume ratio) or drinking containers with greater thermal conductivity. Additionally, our beverage measurement protocol did not include recoding whether sugar was added to tea preparation or to pouring. Sugar may influence the thermal properties of tea, and should be included in future studies. Finally, the study was locally focussed in a small geographical area, a restricted period of the year (January-February) and in a single ethnic group, thus giving rise to further research needs, as follows.

Implications for research

Further studies of hot beverage drinking temperatures should include other population groups, places and times. Specifically, it would be useful to investigate the influence on temperatures of cooler climates in inhabited high altitude areas in Tanzania, Malawi, Kenya's rift valley, and in the Ethiopian Highlands, and of time of the day and season as there is little indoor heating. Non-domestic settings also use different beverage preparation and storage methods. In cafés in Moshi, tea is served in thermal flasks, and the content may be re-boiled before serving. Other settings need investigation, because the high prevalence of hot milky tea may be a peculiarity of this region where milk is abundant and cheap due to strong traditional and smallholder dairy farming [31]. In contrast, black coffee is more common on the coast and is served in the street directly from pots resting on hot coals (Supplementary Figures 4C–4D). Drinking ceremonies in Ethiopia coffee (*buna*) involves three drinking rounds. It would also be useful to examine hot food consumption in the African EC belt, e.g. from frying oils to prepare chapattis, or of porridge in Ethiopia's ESCC high-risk Bale zone (*genfo* or *merka*) [32]. Finally, as infants are weaned onto sweet chai and maize-based porridge by 2 years of age [33–35], studies need to measure temperatures at younger ages. Heat may cause worse injuries to a more sensitive oesophageal epithelium

at this ages, and if injuries occur, they may be linked to the extraordinary occurrence of ESCC under age 30 in Africa [36].

There has been a lack of aetiological studies of EC in this setting. As these are undertaken in the near future, a broad range of risk factors need to be studied for this multi-factorial disease for which risk factors often act synergistically. Thus alongside the consideration of alcohol, tobacco, infections, mycotoxins, nitrosamines, and nutrition, hot beverage drinking should be included. To evaluate the latter's contribution using a case-control design, exposure assessment cannot be based on measured temperatures in dysphagia suffering EC patients. Of self-reported historical exposures, drinking temperature (warm/hot/very hot) was not found to be discriminatory in these participants most of whom reported drinking "hot" tea. However, as substitute or supplementary question, information on tea type (milky/black, milk:water ratio, type of milk (raw, carton, % fat if carton, raw from cow/goat/sheep), and the frequency of tongue-burning represent valuable information correlated with observed drinking temperatures.

Conclusion

An estimated 2000 deaths from oesophageal cancer occurred in Tanzania in 2012, which are expected to rise to 4500 in the year 2035. The present study demonstrates the importance of the evaluation of local and cultural-specific sources and characteristics of risk factors. In this regard, our data confirms that drinking very hot tea on a daily basis from an early age and related to frequent tongue burning is common in this ESCC high incidence region in Tanzania. It demonstrates that tea drinking temperatures are even higher than other international data, particularly for slower cooling milky tea which was linked to more frequent tongue burning. Being a potentially easily modifiable risk factor, the role of hot tea drinking in Tanzania needs to be evaluated directly in relation to esophageal cancer risk in this setting.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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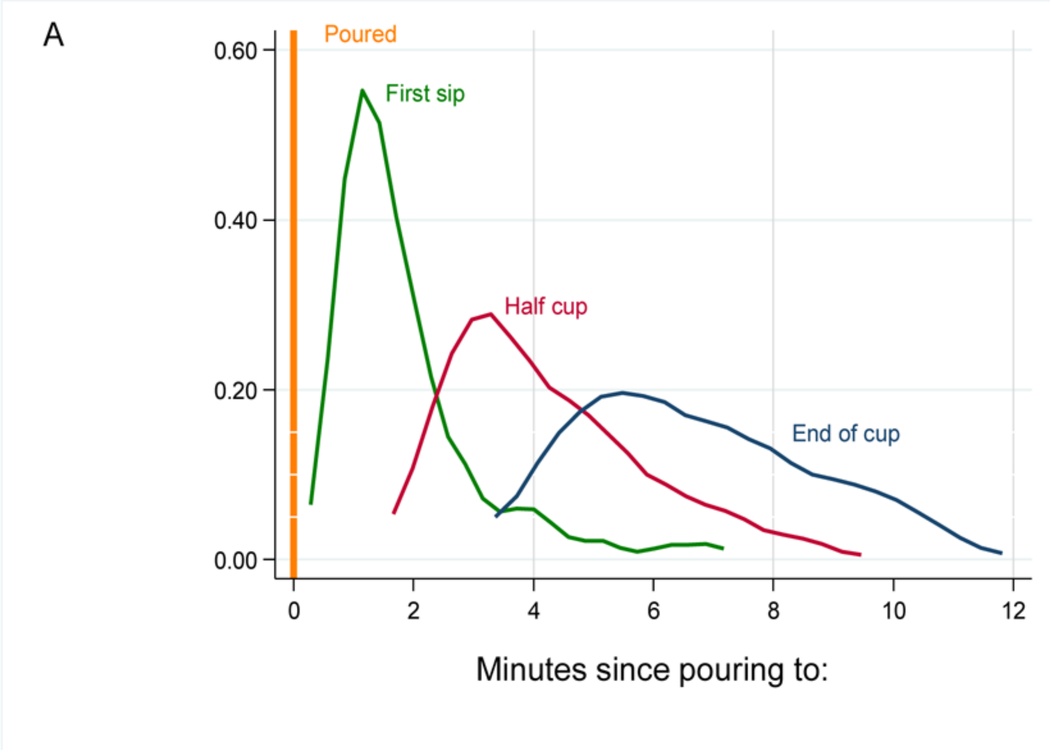
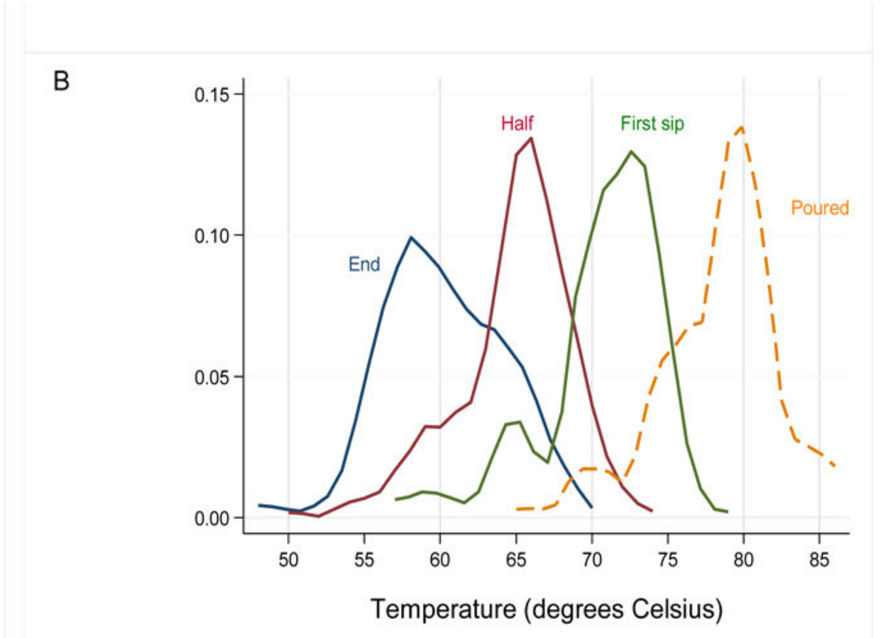

A
Poured
First sip
Half cup
End of cup
0.60
0.40
0.20
0.00
0
2
4
6
8
10
12
Minutes since pouring to:



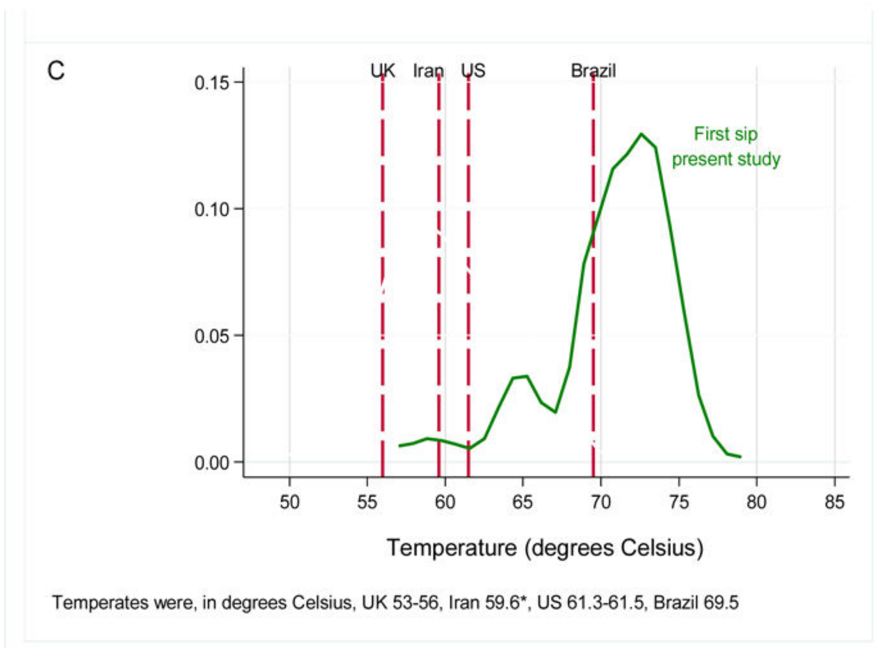


Figure 1.

Smoothed density plots (n=188) of (A) minutes since pouring at first sip, half cup and end of cup; (B) corresponding temperatures; (C) Temperature at first sip, overlaid with means from external studies

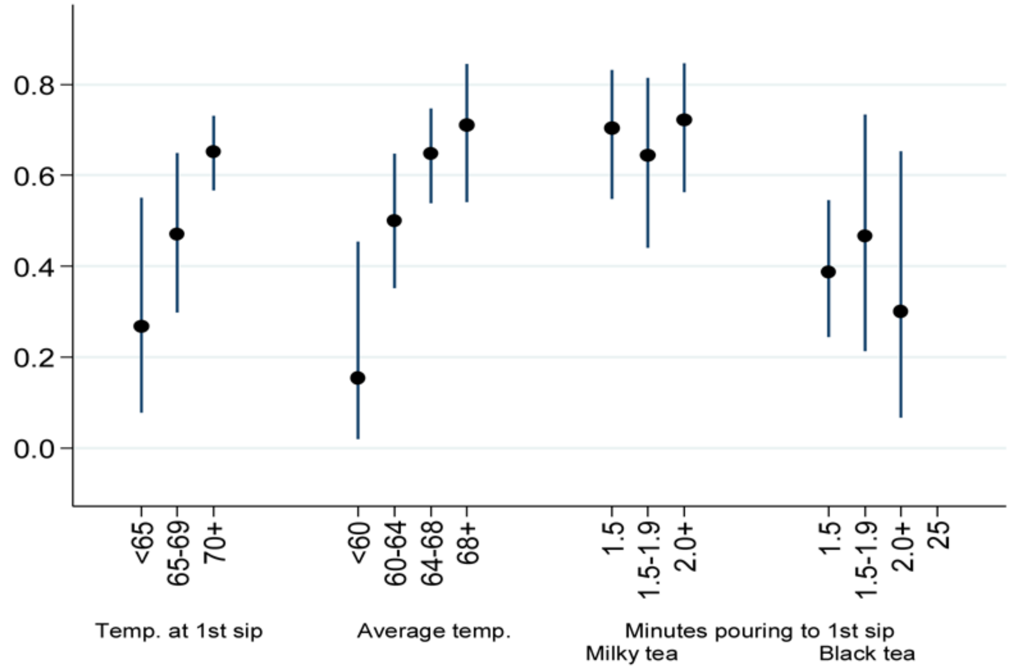


Figure 2.
Proportion of participants with a history of tongue burning, according to drinking characteristics

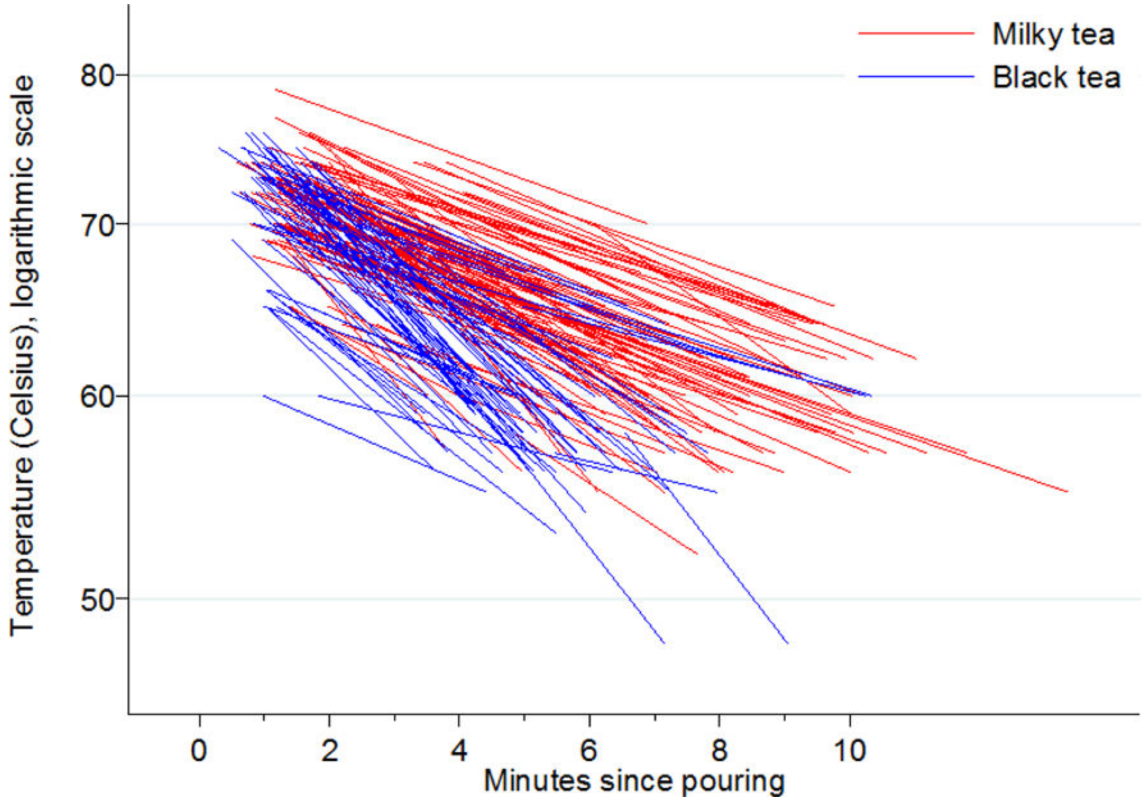


Figure 3.

Median cooling curves of milky and black tea, from a median pouring temperature of 79 Celsius, showing the 20–80th percentiles of the current starting and ending temperatures for each tea type, and the further time needed before the drink reaches 60°C.

Table 1

Characteristics of 188 cross-sectional study participants, Hai district, Kilimanjaro region, Tanzania

Characteristic	N	Column %[a]
Gender		
Male	83	44.2
Female	105	55.9
Age, years		
<30	21	11.2
30–39	24	12.8
40–49	30	16.0
50–59	46	24.5
60–69	28	14.9
≥70	39	20.7
Mean ± SD	52.7 ± 17.1	
Ethnic origin		
Chagga	170	90.4
Other	18	9.6
Occupation		
Farming/at home	128	74.9
Business/outside the home	43	25.2
Level of education		
Primary	144	77.0
Secondary	42	22.5
University	1	0.5
Ever smoked		
Yes	53	28.7
No	132	71.4
Ever drank alcohol		
Yes	131	70.4
No	55	29.6
Electricity		
Yes	83	44.2
No	105	55.9
Piped water supply		
Yes	148	78.7
No	40	21.3
Number of appliances[b] (mean ± SD)	2.6 ± 1.0	
Number of rooms in the home (mean ± SD)	4.4 ± 2.2	

[a]Unless otherwise stated. Column % out of non-missing data. There were no missing data, other than for education (n=1), smoking (n=3), alcohol (n=2), occupation (n=17).

[b]Sum of appliances television, radio, refrigerator, fixed phone, mobile/cell phone, washing machine, electric kettle, and indoor toilet

Table 2

Measured temperatures and times of tea and reported hot beverage drinking habits

Measured hot beverage drinking (tea always chosen)		**N**	**%[a]**
Temperature started drinking °C	<60.0	4	2.1
	60.0–64.9	12	6.4
	65.0–69.9	34	18.1
	70.0–74.9	119	63.3
	≥75	19	10.1
Mean ± SD[b] temperature at: °C	Pouring into cup (T_p)	78.3 ± 3.9	
	First sip (T_0)	70.6 ± 4.0	
	Half-drunk cup (T_h)	64.9 ± 3.8	
	End of cup* (T_f)	60.2 ± 4.0	
	Average over cup** (T_A)	65.2 ± 3.5	
Minutes, pouring to first sip	<1	40	21.4
	1–1.9	93	49.7
	2.0–3.9	40	21.4
	≥ 4	14	7.5
Minutes, first to last sip	*Mean (± SD)*	*5.0 ± 1.8*	
Addition of milk	Before boiling	115	61.2
	After boiling	0	0
	Before and after boiling	1	0.5
	None added	70	37.2
Questionnaire-reported usual hot beverage drinking habits			
Frequency of tea consumption	Daily	188	100
Frequency of coffee consumption, times per week	Daily	7	3.7
	3–5	21	11.2
	1–2	21	11.2
	< Once	18	9.6
	Never	60	31.9
	Missing	61	32.5
Type of tea	Black (no milk)	70	37.2
	Milky tea (milk boiled)	116	61.7
	Cold milk added after	2	1.1
Pattern of drink consumption	Morning + evening, all year	121	64.4
	Morning all year, evening winter	38	20.2
	Morning all year, evening never	28	14.9
	Evening all year, morning never	1	0.5

Measured hot beverage drinking (tea always chosen)		N	%[a]
How hot do you drink beverages?	Very hot	8	4.3
	Hot	171	91.0
	Warm/Cool	9	4.8
How fast do you drink your hot drink compared to others?	Faster	10	5.3
	Same	160	85.1
	Slower	18	9.6
Have you ever burnt your tongue or mouth with a hot drink?	Yes	110	58.8
	No	77	41.2
	No. times in the past year	3.3 ± 1.4	
Age when first started drinking hot drinks (years)	1–2	106	57.6
	3–4	58	31.5
	5+	20	10.9

[*]Fully-drunk cup;.

[a]Column % out of non-missing data. There were no missing data except for: time between pouring and first sip (n=1), addition of milk (n=2), age first started drinking (n=4).

[b]SD=Standard Deviation.

Table 3

Associations of measured tea-drinking temperatures and time drinking tea with participant's characteristics

	Temperatures (°C)				Times (seconds)	
	At pouring	**At first sip**	**Average across cup**	**At end of cup**	**From pouring to first sip**	**From first sip to end of cup**
Overall mean (95% CI)	***78.3 (77.8, 78.8)***	***70.6 (70.1, 71.2)***	***65.2 (64.7, 65.7)***	***60.2 (59.6, 60.8)***	***113s = 1.88 min [102s, 124s]***	***298s = 4.97min (82s, 314s)***
Crude differences	Mean difference (95% CI) i.e. reference = 0					
Milk boiled with water (yes v no)	2.0 (0.8, 3.1)	0.2 (−1.0, 1.3)	1.6 (0.6, 2.6)	2.8 (1.7, 3.9)	35 (13, 57)	75 (44, 107)
Age, per 10 years	0.0 (−0.3, 0.4)	−0.2 (−0.5, 0.2)	−0.3 (−0.6, 0.0)	−0.4 (−0.8, −0.1)	0 (−6, 7)	6 (−3, 16)
Male (vs. female)	0.2 (−0.9, 1.4)	0.8 (−0.3, 1.9)	1.0 (0.0, 2.0)	1.2 (0.1, 2.4)	−19 (−41, 2)	−25 (−57, 6)
Running water (yes vs no)	2.0 (0.6, 3.3)	−0.4 (−1.8, 1.0)	0.9 (−0.3, 2.2)	2.0 (0.7, 3.4)	28 (1, 54)	30 (−8, 68)
Number of appliances	−0.7 (−1.2, −0.1)	−0.4 (−1.0, 0.1)	−0.2 (−0.7, 0.3)	0.0 (−0.6, 0.6)	3 (−8, 14)	−22 (−38, −7)
Ever smoker	0.4 (−0.8, 1.7)	0.7 (−0.6, 2.0)	0.2 (−0.9, 1.3)	−0.2 (−1.5, 1.1)	−15 (−39, 10)	−7 (−42, 28)
Ever drinker	−0.7 (−1.9, 0.6)	−0.1 (−1.3, 1.2)	−0.3 (−1.4, 0.8)	−0.5 (−1.7, 0.8)	−10 (−34, 14)	3 (−31, 38)
Adjusted for addition of milk prior to boiling, age and gender						
Milk boiled with water (yes v no)	2.0 (0.9, 3.2)	0.3 (−0.9, 1.5)	1.9 (0.9, 2.9)	3.2 (2.1, 4.3)	36 (13, 59)	73 (42, 105)
Age (per 10 years)	0.0 (−0.3, 0.4)	−0.2 (−0.6, 0.1)	−0.5 (−0.8, −0.2)	−0.7 (−1.0, −0.4)	1 (−5, 8)	8 (−3, 18)
Male (vs female)	−0.2 (−1.4, 0.9)	0.9 (−0.2, 2.1)	1.3 (0.3, 2.3)	1.6 (0.6, 2.7)	−20 (−43, 2)	−30 (−69, 9)
Running water (yes vs no)	1.1 (−0.5, 2.6)	−0.8 (−2.4, 0.7)	−0.2 (−1.6, 1.1)	0.2 (−1.2, 1.6)	31 (4, 57)	34 (−4, 72)
Number of appliances	−0.7 (−1.2, −0.2)	−0.5 (−1.0, 0.1)	−0.3 (−0.8, 0.2)	−0.1 (−0.6, 0.4)	4 (−7, 14)	−22 (−37, −6)
Ever smoker	0.8 (−0.8, 2.4)	0.6 (−1.0, 2.2)	0.1 (−1.2, 1.4)	−0.3 (−1.8, 1.1)	−6 (−36, 25)	4 (−40, 48)
Ever drinker	−0.9 (−2.4, 0.5)	0.1 (−1.3, 1.6)	0.2 (−1.0, 1.5)	0.3 (−1.0, 1.7)	−10 (−38, 18)	−5 (−45, 36)