

# Does Dark Chocolate Have a Role in the Prevention and Management of Hypertension?

## Commentary on the Evidence

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**Abstract**—The notion that eating chocolate would prevent or treat hypertension is appealing to many who produce and enjoy chocolate. Several studies have documented beneficial effects of dark chocolate on insulin action and endothelial function. However, the published studies on chocolate and blood pressure include a relatively small number of subjects, and results are conflicting. In addition, because of secrecy surrounding the production of chocolate and the unique sociocultural context of this popular food, research on efficacy and effectiveness is complex. This commentary summarizes 13 peer-reviewed studies on dark chocolate and blood pressure and raises questions relevant to its future as an evidence-based lifestyle intervention. (*Hypertension*. 2010;55:1289-1295.)

**Key Words:** chocolate ■ cocoa ■ blood pressure ■ prehypertension ■ hypertension ■ prevention

### *The Hypertension Burden*

Hypertension affects ≈67 million US adults, and another 85 million have prehypertension.<sup>1,2</sup> Although hypertension is an established cardiovascular risk factor,<sup>3</sup> prehypertension only recently received wider attention.<sup>4</sup> Prehypertension is associated with a 3.0-fold greater likelihood of progression to hypertension and 1.4- to 2.0-fold greater risk for cardiovascular events than normal blood pressure (BP) <120/<80 mm Hg.<sup>5</sup>

Lifestyle changes are foundational management for all hypertensive patients and the only management option recommended for most prehypertensives.<sup>4</sup> Hypertension and prehypertension are associated with a cluster of risk factors, including abdominal obesity, hyperinsulinemia, insulin resistance, and vascular dysfunction.<sup>6–8</sup> Although several lifestyle changes, for example, the Dietary Approaches to Stop Hypertension Eating Plan,<sup>4</sup> are efficacious for lowering BP and improving other risk factors, their effectiveness is limited. In fact, Americans are becoming progressively heavier and their diets less like the Dietary Approaches to Stop Hypertension diet over time.<sup>9,10</sup> Thus, simple and effective lifestyle changes, which would be adopted and maintained by a large proportion of prehypertensives, could reduce the burden of prehypertension and hypertension. Dark chocolate/cocoa may be an intervention that could be implemented and maintained by a large proportion of at-risk individuals.<sup>11</sup> A diverse evidence base suggests that cocoa lowers BP while improving insulin sensitivity, vascular function, and cardiovascular outcomes.<sup>12,13</sup>

### *Cocoa, BP, and Cardiovascular Disease: An Ecological Perspective*

The Kuna Indians live on the San Blas Islands off Panama. They consume large quantities of cocoa, and, despite high sodium intake, have a low prevalence of hypertension. Their BP does not rise with age.<sup>14</sup> Kuna Indians who migrate to Panama manifest age-dependent increases of BP and a higher prevalence of hypertension than Kuna Islanders. Thus, Kuna are not genetically protected from hypertension. Kuna Islanders consume ≈10 times more cocoa than those in Panama and have ≈80% less cardiovascular disease. On the basis of this and other evidence, Corti et al<sup>11</sup> proposed that flavanols, especially epicatechin, in cocoa lower BP and improve vascular function and insulin sensitivity while reducing platelet reactivity.

### *Chocolate Within a Sociocultural Context*

Cacao was first brewed as a beer in Mesoamerica >3000 years ago.<sup>15</sup> The Spanish brought cocoa to Europe where local tastes required adding sugar to and heating the cocoa drink. The development of cocoa powder by the Dutch, pralines by the Belgians, and conching to produce smoother chocolate by the Swiss all contributed to various chocolates that we know today.<sup>16</sup> Milk chocolate, which contains less cocoa and added milk, is generally sweeter than dark chocolate. There are national and regional preferences for milk, dark, and white chocolate (cocoa butter, no cocoa). Spaniards, for example, like white chocolate more than Americans.<sup>17</sup> Chocolate processing is also associated with national

Received February 5, 2010; first decision March 1, 2010; revision accepted March 24, 2010.

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The views expressed in this review are the authors and do not necessarily represent the Department of Veterans' Affairs.

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*Hypertension* is available at <http://hyper.ahajournals.org>

DOI: 10.1161/HYPERTENSIONAHA.110.151522

**Table 1. Design Characteristics of Open-Label and Blinded Studies of Dark Chocolate (Cocoa) and BP**

Authors	Study Design	Subjects	Cocoa Dose	Duration
<b>Open-label studies</b>				
Taubert et al <sup>19</sup>	Randomized, open-label, crossover	13 stage 1 ISH, no Rx, 55 to 64 y, 6M/7F, BMI 22 to 26	Ritter sport, 100 g bars (50 g cocoa) vs 100 g WC	14 d DC and WC separated by 7 d washout
Grassi et al <sup>20</sup>	Randomized, open-label, crossover	15 healthy subjects, 34±8 y; 7M/8F, BMI 23±3	Ritter sport, 100 g bars (50 g cocoa) vs 100 g WC	15 d DC and WC separated by 7 d washout
Grassi et al <sup>21</sup>	Randomized, open-label, crossover	20 HTN, no Rx 44±8 y, 10M/10F; BMI 25±2	Ritter sport, 100 g bars (50 g cocoa) vs 100 g WC	15 days DC and WC separated by 7 d washout
Taubert et al <sup>22</sup>	Randomized, open-label, parallel group	44 pre-HTN, stage 1, no Rx, 64±5 y; 21M/23F, BMI 24±2	Ritter sport, 6.3 g (~3.1 g cocoa) vs WC	18 wk parallel DC and WC groups
Grassi et al <sup>23</sup>	Randomized, open label, crossover	19 HTN with IGT, 45±8 y; 11M/8F, BMI <30	100 g Cuorenero DC (50 g cocoa) vs WC	15 d DC and WC separated by 7 d washout
Ried et al <sup>24</sup>	Random, control, parallel group, crossover	26 pre-HTN, ~50±12 y; BMI ~26±5	50 g 70% Haighs DC (35 g cocoa)	8 wk 3 parallel group; 4 wk washout, 8 wk 2 group crossover
Allen et al <sup>25</sup>	Randomized, open cocoa; blind PS, crossover	49 ↑ chol, 46±8 y, 17M/32F, BP <160/<100, no Rx, BMI 28±5	22 g × 2 Cocoa via DC with/without PS	2-wk run-in, 4 wk DC no PS; 4 wk DC+PS, no washout
<b>Double-blind studies</b>				
Fisher et al <sup>26</sup>	Acute and 4 d 821 mg flavanol double-blind	27 healthy subjects, 44±3 y, 11M/16F BMI 27±1	Mars Cocoa Pro (flavanol-rich) vs flavanol poor	Acute and 4 d active and controls
Engler et al <sup>27</sup>	Randomized, double-blind, parallel group	21 healthy subjects, 32±3 y, 11M/10F, BMI 23±1	Mars Dove 46g DC (~25 g cocoa) vs DC low flavanol	2 wk active (n=11), placebo (n=10)
Davison et al <sup>28</sup>	Randomized, double-blind, factorial (exercise)	49 overweight-obese, 45±4 y, 18M/31F, BMI 33±2	High or low polyphenol cocoa, unknown brand, 902 vs 36 mg cocoa flavanols	12 wk parallel group
Muniyappa et al <sup>29</sup>	Randomized, double-blind, crossover	20 HTN, 51±2 y, 8M/12F, BMI 33±1	Mars Cocoa Pro 31 g twice daily or low polyphenol	2 wk active and placebo separated by 7 d washout
Crews et al <sup>30</sup>	Randomized, double-blind parallel group	90 cognitively intact, >60 y, 38M/52F, BMI 25±3	~11 g natural cocoa as DC or drink vs placebo	6 wk
Balzer et al <sup>31</sup>	Randomized, double-masked parallel group	41 diabetic, 63±8 y, 12M/29F, BMI 32±5	Mars Cocoa Pro, 18g 3×/d or placebo	30 d

WC indicates white chocolate; chol, cholesterol; M, male; F, female; HTN, hypertension; DC, dark chocolate; Rx, treatment; BMI, body mass index; PS, polystyrols.

preferences. Swiss chocolate is “conched” 3-times longer than American chocolate, resulting in a smoother consistency. Differences in chocolate composition among European countries resulted in policy disagreements known as the “chocolate war.” National references for chocolate are so important that membership in the European Union includes policies regulating locally produced chocolate. Variations in cocoa processing may impact its biological actions, including the BP effects, which comprise a key limitation in public health recommendations for its consumption to treat and/or prevent hypertension and prehypertension.

### Craving and Social Context

While not reaching a chemical addiction, chocolate craving has been reported.<sup>18</sup> Chocolate is often viewed as a special food with cultural norms for when and how much to eat. Recommendations for dark chocolate as a lifestyle intervention for hypertension and prehypertension should consider the social context and potential for producing chocolate craving with a potential for adverse, unintended consequences.

### Dark Chocolate and BP

A meta-analysis on cocoa and BP identified 5 studies of adequate quality for inclusion.<sup>12</sup> In these reports, cocoa

lowered BP 4.7/2.8 mm Hg ( $P=0.002/0.006$ ). This commentary and review of dark chocolate and BP included these 5 and 8 other original peer-reviewed studies (Tables 1 and 2 and Figure 1).<sup>19–31</sup> Additional references were found in “Ovid” and “Google” searches (last February 3, 2010) using key words including combinations of “dark chocolate”/“chocolate”/“cocoa” and “blood pressure”/“hypertension” from review articles identified in the search and discussions with experts in the field. Studies of <4 days in duration were excluded. Studies were not excluded for methodological concerns, which are noted, thereby allowing the reader to decide the weight that each study should receive.

In the 13 reports, dark chocolate (cocoa) lowered BP in 6 of 7 open-label studies<sup>19–25</sup> but diastolic BP only in 1 of 6 double-blind studies.<sup>26–31</sup> Collectively, these reports raise questions on the BP-lowering efficacy of dark chocolate/cocoa, including the possibility that BP effects are negligible. The review provides potential explanations for disparities in BP effects between the various reports that may inform future studies.

### Placebo Effect

Because cocoa generally lowered BP in open-label but not double-blind studies (Table 2), consideration for a placebo effect

**Table 2. BP Methods and Effects of Dark Chocolate (Cocoa) on BP and Other Selected Variables**

Authors	BP Methods	Baseline BP Mean±SEM	Final BP Mean±SEM	Change BP Mean (95% CI)	Other Effects
<b>Open-label studies</b>					
Taubert et al <sup>19</sup>	Omron HEM-722C after 15-min seated rest at 5 min×3	153.2±1.1 83.8±1.0	148.1±1.0‡ 82.0±1.4‡	−5.1 (−3.8 to 6.4) −1.8 (−0.7 to 2.9)	No Δ BMI, lipids, glucose
Grassi et al <sup>20</sup>	Hg sphyg, blind observer; 10 min seated rest, BP×4 at 3 min, average 3	113.9±2.2 73.2±1.5‡	107.5±2.2 70.1±1.2‡	−6.4 (−4.2 to −8.6)‡§ −3.1 (−0.9 to −5.3)‡NS	↑ Insulin sensitivity
Grassi et al <sup>21</sup>	SpaceLabs 90207 ABPM 15 min day, 30 min night	135.5±1.3 88.0±0.9	123.6±1.4 79.6±1.2	−11.9 (−8.7 to −15.5) −8.5 (−6.3 to −10.7)	↑ Insulin sensitivity ↑ FMD 20%
Taubert et al <sup>22</sup>	Omron HEM-722C after 15 min seated rest at 5 min×3	147.7±1.5 86.4±0.9	144.8 84.5	−2.9 (−2.2 to −3.6) −1.9 (−1.5 to −2.3)	↑ S-nitroso-glutathione (NO)
Grassi et al <sup>23</sup>	SpaceLabs 90207 at 15 min day and 20 min night	134.6±1.0 86.8±0.8	130.1±5.0 86.5±5.7	−4.5 (−2.7 to −6.3) −4.2 (−2.7 to −5.7)	↑ FMD
Ried et al <sup>24</sup>	Omron HEM-907×4 after 5-min seated rest	0 wk: 135.0±3.8 83.6±3.2 12 wk: 129.3±3.0 79.2±2.2	8 wk: 133.1±3.5 80.8±3.8 20 wk: 126.8±2.8 77.8±1.7	−1.9 (NS) +0.9 (NS) −2.5 (NS) −1.3 (NS)	73% of subjects would take DC long-term
Allen et al <sup>25</sup>	Prestige Medical "standard sphyg" after 5 min seated rest×2	118.6±1.9‡ 73.8±1.2‡	4 wk: 109.1±2.2 67.6±1.3‡ 8 wk: 112.9±2.0 72.4±1.1‡	−8.5†‡ −6.2†‡ −5.7*‡ −1.4‡	Only polysterols not cocoa ↓ total and LDL-C
<b>Double-blind studies</b>					
Fisher et al <sup>26</sup>	Dinamap, patient supine, BP×3	Day 0: 117±2.3 68±2.1	Day 4: 117±2.1 66±1.8	No Δ BP acutely 0/−2 at 4 days (NS)	↑ Vascular endothelial function
Engler et al <sup>27</sup>	Dinamap after 5 min supine×2	121±5 68±3	120±4 69±2	−1 (NS) +1 (NS)	↑ FMD
Davison et al <sup>28</sup>	SpaceLabs ABPM 10' supine, 4 BP at 5 min average 3	125.0¶ 77.0	124.7‡ 75.4‡	−0.3 (+3.2, −3.8) −1.6 (0, −3.2)*‡	↑ FMD, insulin sensitivity
Muniyappa et al <sup>29</sup>	Hg sphyg, seated 15 min then at 5-min intervals×3	141±3 91±3	139±2 88±2	−1 (NS/NS) +1 vs placebo	↑ Insulin vasodilation; noΔ insulin sensitivity, adipokines
Crews et al <sup>30</sup>	Advantage 6014, 5 min then 3'×3	126.8 74.2	123.3 73.7	−0.5   +0.1	↑ Heart rate
Balzer et al <sup>31</sup>	?device, patient position, # values	Mean BP 101.0±7.8	Mean BP 101.9±6.9	Mean BP +0.9 (NS)	↑ FMD

NS indicates not statistically significant; FMD, flow-mediated dilation; ABPM, ambulatory BP monitor.

\* $P<0.05$ .

† $P<0.001$ .

‡Values were established from figure(s).

§Values were calculated from baseline BP, mean change.

¶Data show the average baseline BP for 2 high polyphenol groups.

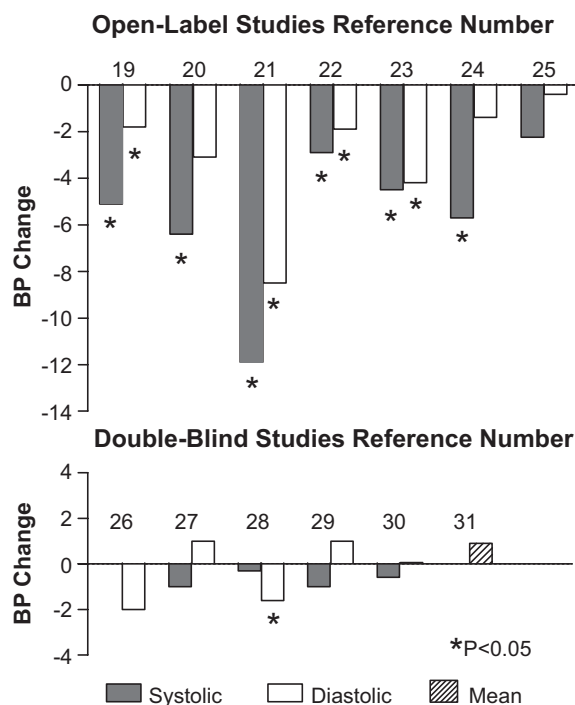
||Placebo was corrected.

must be considered. An individual's anticipation of positive or negative effects can impact the targeted health outcome.<sup>32</sup> In general, greater expected benefit leads to greater health improvement.<sup>33</sup> Individual expectations, including influences from family and friends, can impact the health outcome of interventions in ways not accounted for by study design.<sup>34</sup>

Placebo effect is an unlikely explanation for BP effects of Ritter dark chocolate in randomized, open-label crossover studies.<sup>20–24</sup> In nutritional studies, for example, Dietary Approaches to Stop Hypertension, which are impossible to double blind, findings from randomized, open-label crossover design have been accepted as sufficient for guideline recommendations.<sup>4</sup> The magnitude of the BP effects in the studies by Grassi et al<sup>20,21,23</sup> are of similar order to those with Dietary Approaches to Stop Hypertension. Although the study by Taubert et al<sup>22</sup> with

low-dose Ritter dark chocolate showed a more modest BP reduction, BP change correlated with an NO biomarker.

Taubert et al<sup>22</sup> also noted that double-blind studies with dark chocolate are virtually impossible, because bioactive chemicals in cocoa are bitter. Processing to match taste in flavanol-rich and poor dark chocolate alters the content and composition of cocoa flavanoids, which could alter physiological effects.<sup>22,35,36</sup> Crews et al<sup>30</sup> found that 56% of volunteers in the high- and low-polyphenol chocolate/cocoa groups correctly identified their blinded assignment, which is close to chance. Because chocolate/cocoa did not alter BP in their study, the authors concluded that accurate perception of blinded assignment did not impact outcomes, although results were not compared in volunteers who correctly identified their assignment with those who did not.



**Figure 1.** Mean changes in BP and significance of the changes are shown for open-label (top) and double-blind (bottom) studies of dark chocolate/cocoa and BP. As depicted, significant reductions of BP were observed in 6 of 7 open-label studies but diastolic BP only in 1 of 6 double-blind studies. Note that the 8-week BP results are shown for the study by Allen et al.<sup>25</sup> and the mean systolic and diastolic BPs are shown for the 2 groups combined in the study by Ried et al.<sup>24</sup>

### BP Measurement Methodology

There are considerable variations in BP methods reported in 13 peer-reviewed reports on dark chocolate and BP. Among open-label studies, the Omron HEM 722C monitor used by Taubert et al<sup>19,22</sup> received an “A” rating for accuracy using the British Hypertension Society protocol.<sup>37</sup> The SpaceLabs 90207 ambulatory BP monitor used in 2 of the studies by Grassi et al<sup>21,23</sup> received a “B” rating for accuracy for both systolic and diastolic BPs.<sup>38</sup> The limited accuracy of the SpaceLabs ambulatory monitor for measuring changes in mean systolic and diastolic BPs is mitigated by obtaining a large number of measurements over 24 hours.

Using the SpaceLabs 90207 for 4 laboratory BP readings in a double-blind study of dark chocolate and BP is a greater concern given the limited number of measurements.<sup>28</sup> Two double-blind studies<sup>26,27</sup> used the previous-generation Dinamap, which received grades of “C” or lower for BP accuracy.<sup>39</sup> Another double-blind study did not describe the BP measurement device, position of volunteers, or number of readings.<sup>30</sup> The double-blind study by Muniyappa et al<sup>29</sup> reported acceptable BP measurement methods. The study by Crews et al<sup>30</sup> also appeared to use accepted BP measurement methodology.

In summary, open-label studies reporting that dark chocolate lowered BP generally described well-accepted methods for measuring BP. In contrast, except for 2 reports,<sup>29,31</sup> double-blind studies provided limited detail or used devices with suboptimal accuracy.

### Brand of Dark Chocolate

Four open-label studies selected Ritter dark chocolate with 50% cocoa, and all 4 documented significant BP reduction (Tables 1 and 2). In 3 studies, 100 g with 50% cocoa and 480 kcal were given daily for 14 to 15 days.<sup>19–21</sup> Systolic BP declined 5 to 11 mm Hg after 2 weeks. In the fourth study, the daily dose was 6.3 g of dark chocolate with ≈30 calories and 3.1 g cocoa daily.<sup>22</sup> Systolic BP declined 2.9 mm Hg after 18 weeks, which was statistically significant. Low-“dose” Ritter dark chocolate did not lower BP significantly at 6 and 12 weeks. Thus, Ritter dark chocolate with 50.0 g of cocoa daily appears to lower BP more rapidly and to a greater extent than 3.1 g cocoa daily. However, the large dose (≈480 kcal) would constitute ≈20% to 25% of total daily calories for most people, which may be impractical long term.

Four double-blind studies selected Mars dark chocolate.<sup>26,27,29,30</sup> The Mars Cocoa Pro/Dove products improved vascular endothelial function in all of the studies, yet none significantly lowered BP. Differences in BP effects of Ritter and Mars dark chocolate/cocoa suggest significant variations in chemical and biological properties of the 2 brands. Comparisons are further complicated by conduct of only open-label studies with Ritter and double-blind studies with Mars products.

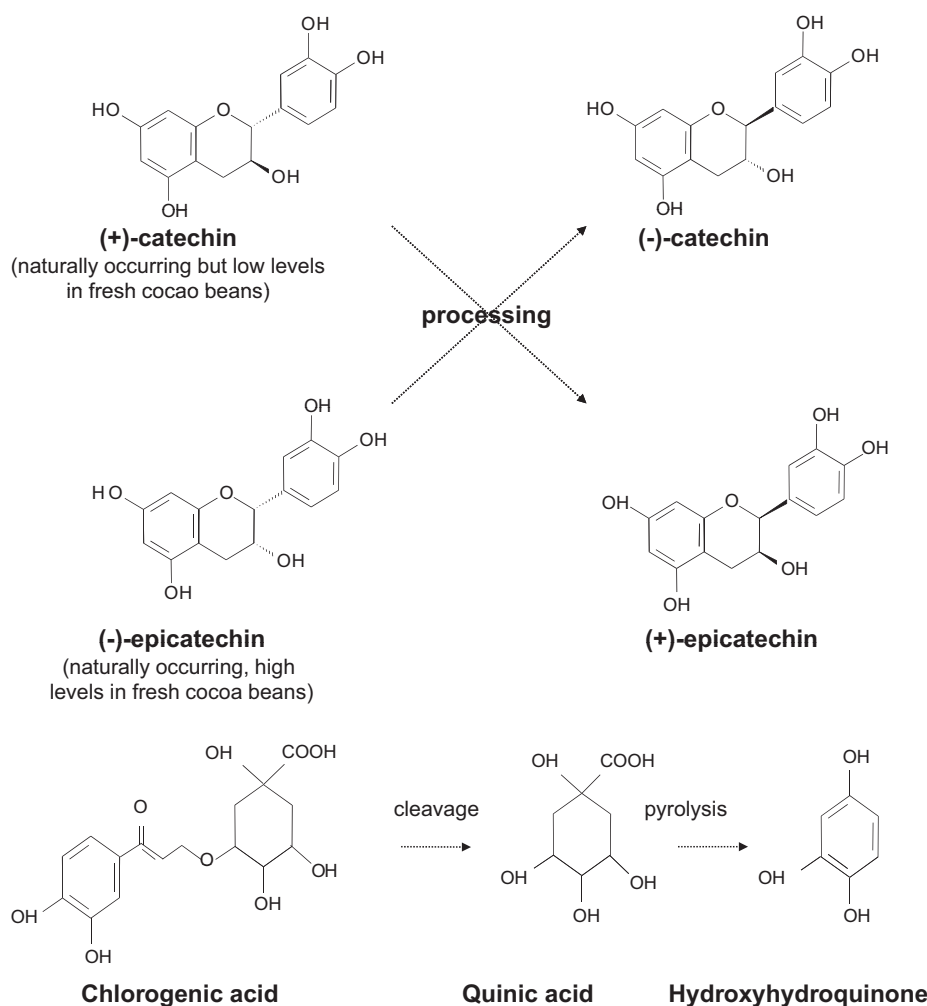
### Variations in Chemical Content of Dark Chocolate/Cocoa and Biological Implications

Cocoa is rich in flavanols (mainly epicatechin) and their polymeric form, procyanidins. Flavanols, especially epicatechin, appear responsible for several beneficial effects of cocoa/chocolate.<sup>11</sup> In a landmark study, epicatechin was strongly linked to beneficial effects on vascular endothelial function.<sup>13</sup>

The extant literature provides few clues on the mechanism(s) by which some cocoa products appear to lower BP. In vitro studies have not provided convincing evidence that a particular component or components of dark chocolate/cocoa lower BP.<sup>40</sup> As one potential mechanism, angiotensin-converting enzyme inhibitors are effective antihypertensive agents, and procyanidins in cocoa and specific flavanols in other foods inhibit angiotensin-converting enzyme activity in vitro.<sup>41</sup> The lowest flavanol concentrations used in the in vitro studies, however, are much higher than those expected after consuming chocolate.

In a recent preliminary report, epicatechin induced a dose-dependent reduction of BP in an animal model of hypertension induced by inhibiting NO synthase,<sup>42</sup> which coincides with the study by Taubert et al<sup>22</sup> showing that dark chocolate increased an NO biomarker in humans. However, there is no apparent correlation between the epicatechin content of dark chocolate/cocoa studied and BP change. The variable effects of dark chocolate/cocoa on BP may reflect differences in content of chemicals that lower BP and/or others that raise BP, for example, 5-fold differences in the epicatechin:catechin ratio.<sup>43</sup> Those chemical differences could reflect variations in cocoa bean genetics or processing (Figure 2).

Genetic and differences in cocoa beans can explain up to 4-fold differences in flavanol content.<sup>35</sup> *Theobroma cacao* is grown mainly on small farms near the equator. Beans from several small farms are combined, where they typically undergo initial processing. The chemical composition of cocoa beans varies based on cultivar (ie, genetics), as well as geographical location and seasonal environmental changes.



**Figure 2.** Top, Epimerization of flavanols in chocolate (cocoa) occurs, and (–)-epicatechin creates the nonnaturally occurring enantiomer of catechin. Bottom, Formation of hydroxyhydroquinone during coffee processing. When coffee beans are roasted, chlorogenic acid and related quinic acid esters are cleaved, releasing quinic acid. Quinic acid is converted to hydroxyhydroquinone.

Most producers purchase beans from several countries and blend beans for their products.<sup>36</sup> Even the same manufacturer may use a different blend of beans for its products, for example, Ritter's 50% and 71% dark chocolates.<sup>44</sup> Most producers do not report their source(s) of cocoa beans.

Variations in cocoa bean processing can dramatically alter chemical composition of the final product. Fermentation, roasting, and alkali treatment, while improving flavor, reduce flavanol content.<sup>35,36</sup>

Cocoa processing could produce compound(s) that counteract its BP-lowering effects analogous to coffee processing. Green coffee bean (unroasted) extracts lower BP.<sup>45,46</sup> The BP effects appear to be mediated by chlorogenic acid and related hydroxycinnamates.<sup>47,48</sup> However, roasting coffee beans produces hydroxyhydroquinone that negates the BP-lowering effects of coffee (Figure 2).<sup>45–48</sup>

Although chocolate contains epicatechin and catechin, *T. cacao* produces very little catechin. The (–)-catechin is formed by epimerization of (–)-epicatechin during processing (Figure 2). The content of (–)-catechin varies widely between chocolate products, which provides indirect evidence for variability in processing techniques.<sup>43</sup> Although little is known about biolog-

ical activity of (–)-catechin, the 2 enantiomers showed opposite effects on glycogen metabolism in isolated rat hepatocytes.<sup>49</sup> Femoral artery vasodilation in rats was observed after a bolus of 10 nM (–)-epicatechin, but no effect was observed using concentrations of (–)-catechin  $\leq 1000$  nM.<sup>50</sup> Although the contribution of (–)-catechin to chocolate's BP effect is unclear, it appears plausible that (–)-catechin counteracts BP-lowering effects of (–)-epicatechin and may explain the lack of BP effects in some cocoa studies.

#### **Vasodilators Are Not Always Antihypertensive**

In most hypertensives, elevated BP is linked with increased vascular resistance.<sup>51</sup> It is sometimes assumed that reducing vascular resistance will always lower BP. Although peripheral vasodilators can lead to short-term BP reduction, the kidney is overwhelmingly the dominant controller of long-term BP.<sup>52</sup> Unless the renal pressure threshold for maintaining sodium homeostasis is set at a lower level either by direct or indirect actions on the kidney, then long-term BP will not change significantly. Thus, cocoa's vasodilatory effects will not produce sustained reductions in BP unless resetting of the renal threshold for pressure natriuresis to a lower level occurs.<sup>52</sup>



## Unanswered Questions

Several unanswered questions must be addressed before dark chocolate can be recommended as a lifestyle intervention for hypertension and prehypertension.

### *Does the Brand of Dark Chocolate Account for Differences in BP Effects?*

In all 4 of the open-label studies with Ritter dark chocolate, BP fell, whereas BP did not change significantly in all 4 of the double-blind studies with Mars/Dove cocoa/dark chocolate. Differences in study design limit direct comparison. No published reports were found comparing BP effects of different dark chocolates in the same study. If BP is altered differentially by various brands of dark chocolate, this information could facilitate efforts to identify the source of those differences, maximize the BP benefits of cocoa/dark chocolate, and produce nutraceuticals that lower BP.

### *What Are the Dose- and Time-Dependent Effects of Dark Chocolate on BP?*

If the chemical properties mediating the BP effects of dark chocolate are identified and/or BP-lowering effects of  $\geq 1$  brand of dark chocolate are confirmed, then additional pharmacodynamic information is needed. Guidance must be provided on the dose (amount) of dark chocolate and frequency of ingestion required to provide a clinically significant BP response maintained for 24 hours and sustained long term. Patients and providers need guidance on the length of time after implementation to obtain an effect, the interindividual heterogeneity in responses, and any factors that predict responsiveness.

### *What Is the Impact of Variable BP and Its Measurement on the Heterogeneity of BP Responses to Dark Chocolate?*

Intraindividual BP variability is substantial and compounded by measurement limitations. A BP that is both accurate, that is, in close agreement with a gold standard, and representative of average or usual readings would be valuable.<sup>53</sup> Physiological variability and measurement errors generally mask rather than create significant BP results. In addition to increasing sample size, obtaining accurate and representative BP in the clinical setting and including 24-hour monitoring when feasible are important.<sup>54,55</sup>

### *What Is the Explanation for the Apparent Dissociation of the BP, Metabolic, and Vascular Effects of Dark Chocolate?*

Clinical studies with Ritter and Mars dark chocolate/cocoa reported improved insulin action (sensitivity) and vascular function.<sup>21,29,30</sup> Yet, only Ritter dark chocolate consistently lowered BP (Table 2). Because details of cocoa processing appear to be closely guarded “trade secrets” and are likely to have a dynamic element, the chemical properties of various brands may change over time. Thus, it becomes even more important to delineate chemical properties of cocoa that mediate beneficial actions.

### *Will Populations at Risk for Hypertension and Prehypertension Eat Therapeutic Doses of Dark Chocolate?*

Trials that test health benefits of dark chocolate should assess whether it will be eaten by the targeted population in amounts and frequencies with demonstrated efficacy. Individual preferences for and beliefs about health benefits of chocolates tested should be assessed.

A qualitative analysis of participant “lived experiences” in clinical trials of chocolate is needed to better understand the individual and social contexts of the trial, adherence to eating different dark chocolates, and feasibility of widespread adoption. In the study by Ried et al,<sup>24</sup> 73% of subjects indicated they would consume 50 g of dark chocolate daily as a long-term intervention, including a substantial minority that was not thrilled with the idea. This finding suggests that a large proportion of hypertensives and prehypertensives would consume a relatively large amount of dark chocolate if important health benefits are established.

## Perspective

Prehypertension and hypertension affect approximately two thirds of US adults. Lifestyle interventions are foundational therapy for all hypertensives and the only intervention recommended for most prehypertensives. Several lifestyle options lower BP and improve other cardiovascular risk factors, but population effectiveness is limited because of low adoption and maintenance. Historical, ecological, and clinical trial evidence suggest that dark chocolate can improve insulin sensitivity and vascular endothelial function and possibly lower BP. Several open-label studies reported that dark chocolate lowered BP among volunteers with a wide range of ages and baseline BPs. These studies suggest that dark chocolate could be useful for the prevention and management of hypertension in a broad segment of the population.

Addressing the unanswered questions through high-quality research has potential to establish that dark chocolate/cocoa lowers BP and to optimize its antihypertensive effects while retaining and even amplifying other beneficial actions. The research portfolio should seek to identify adverse effects of dark chocolate and to define the proportion of the at-risk population for whom it is an acceptable long-term intervention. Addressing the unanswered questions may lead to a palatable recommendation for reducing cardiovascular risk for millions of prehypertensive and hypertensive people.

## Disclosures

None.

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