Minced beef is more rapidly digested and absorbed than beef steak, resulting in greater postprandial protein retention in older men

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ABSTRACT
Background: Older individuals generally experience a reduced food-chewing efficiency. As a consequence, food texture may represent an important factor that modulates dietary protein digestion and absorption kinetics and the subsequent postprandial protein balance.

Objective: We assessed the effect of meat texture on the dietary protein digestion rate, amino acid availability, and subsequent postprandial protein balance in vivo in older men.

Design: Ten older men (mean ± SEM age: 74 ± 2 y) were randomly assigned to a crossover experiment that involved 2 treatments in which they consumed 135 g of specifically produced intrinsically L-[1-13C]phenylalanine–labeled beef, which was provided as beef steak or minced beef. Meat consumption was combined with continuous intravenous 1-[ring-2H5]phenylalanine and 1-[ring-2H2]tyrosine infusion to assess dietary protein digestion and absorption kinetics as well as whole-body protein balance and skeletal muscle protein synthesis rates.

Results: Meat protein–derived phenylalanine appeared more rapidly in the circulation after minced beef than after beef steak consumption (P < 0.05). Also, its availability in the circulation during the 6-h postprandial period was greater after minced beef than after beef steak consumption (61 ± 3% compared with 49 ± 3%, respectively; P < 0.01). The whole-body protein balance was more positive after minced beef than after beef steak consumption (29 ± 2 compared with 19 ± 3 μmol phenylalanine/kg, respectively; P < 0.01). Skeletal muscle protein synthesis rates did not differ between treatments when assessed over a 6-h postprandial period.

Conclusions: Minced beef is more rapidly digested and absorbed than beef steak, which results in increased amino acid availability and greater postprandial protein retention. However, this does not result in greater postprandial muscle protein synthesis rates. This trial was registered at clinicaltrials.gov as NCT01145131.

INTRODUCTION
Aging is accompanied by a progressive decline in skeletal muscle mass, which is termed sarcopenia (1). Work has shown that the anabolic response to food intake is impaired in older adults (2–5). This proposed anabolic resistance is now regarded as a key factor in the cause of sarcopenia.

Dietary protein–derived amino acids serve as the main building blocks for de novo muscle protein synthesis (6). As such, the postprandial muscle protein synthetic response to food intake strongly depends on the quantity (7, 8) and quality (9, 10) of dietary protein consumed. The ingestion of dietary protein stimulates whole-body protein synthesis and inhibits protein-breakdown rates, which results in a positive net protein balance (11). However, the magnitude of this positive protein balance seems to depend on both the rate at which dietary proteins are digested as well as the age of the consumer (9, 12–14). Although young adults generally show a more-positive whole-body protein balance after consumption of slowly digestible protein sources, older adults show a more positive whole-body protein balance after ingestion of protein sources that are more rapidly digestible (9, 12–14).

Meat is considered a high-quality and widely consumed protein source. The texture of the consumed meat plays a key role in the chewing efficiency and subsequent bolus formation during mastication (15). Aging has been associated with decreased chewing efficiency, which leads to a lower disruption of swallowed meat pieces (16). However, the consequences of meat texture on the dietary protein digestion rate, plasma amino acid availability, and subsequent postprandial protein retention remain to be established.

To directly and accurately assess the appearance rate of dietary protein–derived amino acids from the gut into the circulation, dietary protein with a labeled amino acid incorporated within its protein matrix is warranted (17). However, such intrinsically labeled dietary protein is not commercially available, and only a few reports have described the production of intrinsic stable-isotope–labeled dietary proteins for the purpose of nutrition research (18–20). Recently, we succeeded in producing intrinsically labeled protein by infusing large amounts of L-[1-13C] Phe in a Holstein cow. Besides collecting intrinsically labeled milk, we also butchered the cow and, thereby, obtained intrinsically labeled meat certified for human consump-

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tion (21). The latter method was the unique feature of the study and allowed us to directly assess meat protein digestion and absorption kinetics in vivo in humans.

In the current study, 10 older men were randomly assigned to a crossover experiment in which they consumed 135 g of intrinsically L-[1-13C]Phe–labeled beef, which was provided either as a minced beef patty or as beef steak. We hypothesized that minced beef is more rapidly digested and absorbed than beef steak, which results in increased amino acid availability and greater postprandial protein retention in older males.

SUBJECTS AND METHODS

Subjects

Ten elderly men (mean ± SEM age: 74 ± 2 y; weight: 79.3 ± 3.3 kg; BMI (in kg/m²): 26.2 ± 0.8; basal glucose concentration: 5.7 ± 0.1 mmol/L; basal insulin concentration: 16.0 ± 1.2 mU/L) participated in this study. All subjects were recruited in March and April 2011 and wore dentures for ≥6 mo. None of the subjects had a history of participating in any regular exercise program. All subjects were informed on the nature and possible risks of the experimental procedures before written informed consent was obtained. This study was approved by the Medical Ethics Committee of the Academic Hospital Maastricht.

Pretesting

Before selection in the study, an oral glucose tolerance test was performed to assess glucose tolerance and screen for type 2 diabetes prevalence according to WHO criteria (22). Before the oral glucose tolerance test, body weight and height were assessed, and body composition was determined, by using dual-energy X-ray absorptiometry (Discovery A; Hologic Inc).

Diet and activity before testing

All subjects consumed a standardized meal (32 ± 2 kJ/kg body weight, which consisted of 55% of energy from carbohydrate, 15% of energy from protein, and 30% of energy from fat) the evening before the experiment. All volunteers were instructed to refrain from any sort of exhaustive physical activity and to keep their diet as constant as possible 3 d before experiments.

Experiments

All subjects were randomly assigned (unrestrictedly by BP) to a crossover experiment that involved 2 treatments in which they consumed a 135-g piece of intrinsically L-[1-13C]Phe–labeled beef, either minced as a beef patty or intact as a steak. Subjects and researchers who administered the treatment were not blinded; only individuals who assessed outcomes were blinded. Both treatments were separated by ≥14 d. Each treatment started at 0800, when overnight-fasted subjects arrived at the laboratory by car or public transportation. A polytetrafluoroethylene catheter was inserted into an antecubital vein for stable-isotope infusion. A second polytetrafluoroethylene catheter was inserted in a heated dorsal hand vein of the contralateral arm and placed in a hot box (60°C) for arterialized blood sampling (23). After basal blood collection (t = −150 min), plasma Phe and Tyr pools were primed with a single intravenous dose of L-[ring-2H₅]Phe (2 μmol/kg) and L-[ring-2H₂]Tyr (0.615 μmol/kg), after which a continuous L-[ring-2H₅]Phe and L-[ring-2H₂]Tyr infusion was started (0.050 ± 0.001 and 0.015 ± 0.002 μmol · kg⁻¹ · min⁻¹, respectively). After resting in a supine position for 60 min, a second arterialized blood sample was drawn, and a muscle biopsy was collected from the vastus lateralis muscle (t = −90 min). Additional arterialized blood samples (6 mL) were collected at t = −60, −30, and 0 min with a second muscle biopsy taken at t = 0 min, which marked the end of the fasting basal period. Subjects received the meat meal to which they were allowed to add (the same amount of) salt and drink a glass of water. The time that subjects needed to consume the entire meal was recorded. After the consumption of the entire meal, subjects filled in a visual analog scale (VAS) questionnaire on the effort perceived of chewing the meat before swallowing. Arterialized blood samples were collected at t = 30, 60, 90, 120, 150, 180, 240, 300, and 360 min after the complete consumption of the meat meal. A third muscle biopsy taken from the vastus lateralis of the contralateral limb was obtained at 360 min to mark the end of the postprandial period. Blood samples were collected in tubes containing EDTA and centrifuged at 1000 × g for 5 min at 4°C. Aliquots of plasma were frozen in liquid nitrogen and stored at −80°C. Muscle biopsies were obtained from the middle region of the vastus lateralis, 15 cm above the patella and ~3 cm below entry through the fascia, by using the percutaneous needle-biopsy technique. Muscle samples were dissected carefully and freed from any visible nonmuscle material. Muscle samples were immediately frozen in liquid nitrogen and stored at −80°C until additional analysis.

Preparation of intrinsically labeled meat

Intrinsically L-[1-13C]Phe–labeled meat was obtained by infusing a Holstein cow with large quantities of L-[1-13C]Phe as described previously (21). Twenty-four hours after the infusion period, the cow was transported to a commercial abattoir (Henk Worst) and slaughtered. The carcass was refrigerated at 4°C for 2 d postmortem. Thereafter, the carcass was deboned, and meat cuts from the right leg were weighed in portions of 135 g and stored at −18°C. Before packaging and storage, part of the lean beef was minced to guarantee that meat from the same cut could be provided as a minced beef patty and beef steak. On the morning of the test day, meat meals were prepared in the kitchen of the Department of Human Movement Sciences. In short, meat meals (thawed overnight in a refrigerator at 4°C) were grilled until the inner temperature reached 65°C. The meat met all chemical and bacteriologic specifications for human consumption. The L-[1-13C]Phe enrichment, which was assessed by using gas chromatography–combustion isotope ratio mass spectrometry after hydrolysis, was 1.47 ± 0.03 molar percent excess. The protein content was ~19 g protein per 100 g (raw) beef. As such, 135 g beef provided ~26 g protein and ~2 g Leu.

VAS questionnaire

After the consumption of the entire meal, subjects filled in a VAS questionnaire on the effort perceived to chew the meat.
before swallowing. Subjects specified their answers by indicating a position along a continuous 10-cm line between 2 endpoints [ie, not much effort (0 cm) and a lot of effort (10 cm)].

Plasma analyses

Plasma glucose (Uni Kit III, 07367204; Roche) concentrations were analyzed with a COBAS-FARA semiautomatic analyzer (Roche). Insulin was analyzed by using a radioimmunoassay (Insulin RIA kit; LINCO Research Inc). Plasma (100 μL) for amino acid analyses was deproteinized on ice with 10 mg dry 5-sulphosalicylic acid, mixed, and the clear supernatant fluid was collected after centrifugation. Plasma amino acid concentrations were determined by using HPLC after precolumn derivatization with o-phthalaldehyde (24). For plasma ring-2H enrichment measurements, plasma Phe and Tyr were derivatized to their t-butyldimethylsilyl derivatives and analyzed by using gas chromatography–mass spectrometry (GC-MS) (Agilent 6890N GC/5973N MSD; Agilent) by using selected ion monitoring of masses 336 and 341 for unlabeled and labeled (ring-2H5) Phe, respectively; and masses 466, 468, and 470 for unlabeled and labeled (ring-2H2 and ring-2H3) Tyr, respectively (25). For plasma 1-13C enrichment measurements, Phe was derivatized to its N(O,S)-ethoxycarbonyl ethyl ester (26). Thereafter, ratios of labeled:unlabeled derivatives were analyzed by using gas chromatography–combustion isotope ratio mass spectrometry (Finnigan MAT 252; ThermoFisher Scientific). Standard regression curves were applied in all isotopic enrichment analyses to assess the linearity of the mass spectrometer and to control for the loss of tracer.

Muscle analyses

For the measurement of l-[ring-2H3]Phe enrichment in the muscle tissue–free amino acid pool and mixed muscle protein, 55 mg wet muscle was freeze-dried. Collagen, blood, and other nonmuscle fiber material were removed from muscle fibers under a light microscope. The isolated muscle fiber mass (10–15 mg) was dried under a nitrogen stream while heated to 120°C, and a 50% acetic acid solution was added, and the hydrolyzed protein was passed over a Dowex exchange resin (AG 50W-X8, 100–200 mesh hydrogen form; BioRad) by using 2 mol/L NH4OH. The eluate was collected, and l-[ring-2H3]Phe was derivatized to its N-methyl-N-tert-butyldimethylsilyltrifluoroacetamide-phenyl-ethylamine (26). Thereafter, ratios of labeled:unlabeled derivatives were determined by using GC-MS. Standard regression curves were applied to assess the linearity of the mass spectrometer and to control for the loss of tracer.

Calculations

The ingestion of l-[1-13C]Phe–labeled meat, intravenous infusion of l-[ring-2H3]Phe and l-[ring-2H2]Tyr, and arterIALIZED blood sampling were used to assess whole-body protein metabolism in non–steady state conditions. The total, exogenous, and endogenous Phe rate of appearance (Ra) and plasma availability of dietary Phe (ie, fraction of dietary Phe that appeared in the systemic circulation (Pheplasma) were calculated by using modified Steele’s equations (13, 27). These variables were calculated as follows:

\[
R_a = \frac{F - pV \times C(t) \times dE_{iv}/dt}{E_{iv}(t)}
\]

\[
ExoR_a = \frac{TotalR_a \times E_{po}(t) + pV \times dE_{po}/dt}{E_{prot}}
\]

\[
Endo = R_a = total R_a - ExoR_a - F
\]

\[
Phe_{plasma} = \left( \frac{AUC_{Exo}R_a}{Phe_{prot}} \right) \times BW \times 100
\]

where \(F\) is the intravenous tracer infusion rate (μmol · kg⁻¹ · min⁻¹), \(pV (0.125)\) is the distribution volume for Phe (27). \(C(t)\) is the mean plasma Phe concentration between 2 time points. \(dE_{iv}/dt\) represents the time-dependent variations of plasma Phe enrichment derived from the intravenous tracer, and \(E_{po}(t)\) is the mean plasma Phe enrichment from the intravenous tracer between 2 consecutive time points. \(ExoR_a\) represents the plasma entry rate of dietary Phe, \(E_{prot}(t)\) is the mean plasma Phe enrichment for the oral tracer, \(dE_{po}/dt\) represents the time-dependent variations of plasma Phe enrichment derived from the oral tracer, and \(E_{prot}(t)\) is the l-[1-13C]Phe enrichment in the dietary protein. \(Endo\) \(R_a\) represents the plasma entry of Phe derived from whole-body protein breakdown. \(Phe_{exo}\) is the amount of dietary Phe ingested, AUCExoR\(a\) represents the AUC of Exo \(R_a\), which corresponds to the amount of dietary Phe that appeared in the blood over the 6-h period after meat consumption, and \(BW\) represents the subject’s body weight in kilograms.

The total rate of disappearance of Phe (total \(R_d\)) equals the Phe-to-Tyr conversion rate (first step in Phe oxidation) and utilization for protein synthesis. These variables were calculated as follows:

\[
TotalR_d = totalR_a - pV \times dC/dt
\]

\[
PHE to TYR conversion = TyrR_a \times E_t(t) \times \frac{PheR_d}{(F_p + PheR_d)}
\]

\[
Protein synthesis = total R_d - PHE to TYR conversion
\]
PHE net balance = protein synthesis − Endo \( R_a \) (8)

where Phe \( R_a \) and Tyr \( R_a \) are the flux rates for Phe and Tyr, respectively; \( E(t) \) and \( E_p(t) \) are the mean plasma enrichments of \( L-[\text{ring}-2\text{H}_4]Tyr \) and \( L-[\text{ring}-2\text{H}_5]Phe \), respectively; and \( F_p \) is the infusion rate of the Phe tracer.

The fractional synthetic rate (FSR) of mixed muscle protein (in %/h) was calculated by using the precursor-product method (25):

\[
FSR = \frac{\Delta E_p}{E_{\text{precursor}} \times t_\text{inc}} \times 100
\]

where \( \Delta E_p \) is the \( \Delta \) increment of muscle protein-bound \( L-[\text{ring}-2\text{H}_5]Phe \) during the incorporation period. \( E_{\text{precursor}} \) is the average plasma \( L-[\text{ring}-2\text{H}_5]Phe \) enrichment during the time period for determination of amino acid incorporation, and \( t \) indicates the time interval (h) between biopsies.

Statistics

A 2-factor repeated-measures ANOVA with time and treatment as within-subject factors was used to assess differences between treatments over time (time \( \times \) treatment interaction). In case of a significant time \( \times \) treatment interaction, pairwise comparisons for individual time points were applied to locate differences between treatments. For non–time-dependent variables, a paired \( t \) test was used to compare differences between treatments.

We hypothesized that minced beef is more rapidly digested and absorbed than beef steak, which would result in increased amino acid availability and greater postprandial protein retention in older men. As such, the primary outcomes for evaluating the study hypothesis were exogenous Phe \( R_a \) and whole-body net protein balance.

The sample-size calculation, with a 2-sided significance level of 0.05 and power of 0.8, was based on differences in protein digestion and absorption kinetics as described previously (14). The sample size was estimated at \( n = 10 \). Statistical significance was set at \( P < 0.05 \). All calculations were performed with the SPSS 19.0.1.1 software package (SPSS Inc). All data are expressed as means \( \pm \) SEMs.

RESULTS

Meal consumption time and VAS questionnaire

Subjects required more time to consume the beef steak than minced beef (14.4 \( \pm \) 2.6 and 5.1 \( \pm \) 0.4 min, respectively; \( P < 0.01 \)). In addition, subjects reported via VAS questionnaires that it took them more effort to chew the beef steak before swallowing than the minced beef (7.8 \( \pm \) 0.9 compared with 1.0 \( \pm \) 0.4 cm, respectively; \( P < 0.01 \)).

Plasma analyses

Plasma insulin concentrations increased after meat consumption, which peaked at 90 min and returned back to baseline concentrations by 240 min with no differences between treatments (Figure 1). Plasma glucose concentrations did not change over time or between treatments and averaged 5.1 \( \pm \) 0.1 mmol/L for both treatments. Plasma Phe, Leu, and essential amino acid (EAA) concentrations over time are illustrated in Figure 2. Plasma EAA concentrations increased after meat consumption and peaked at 120 min. No differences were observed between treatments.

Time courses of plasma \( L-[\text{ring}-2\text{H}_5]Phe \) and \( L-[\text{ring}-2\text{H}_5]Phe \) enrichments are illustrated in Figure 3. Plasma \( L-[\text{ring}-2\text{H}_5]Phe \) enrichments (intrinsically labeled meat protein–derived Phe) rapidly increased after consumption of test meals, with a higher average enrichment observed after minced beef consumption than after beef steak consumption (\( P < 0.01 \)). Plasma \( L-[\text{ring}-2\text{H}_5]Phe \) enrichments (from a continuous \( L-[\text{ring}-2\text{H}_5]Phe \) infusion) initially decreased after beef consumption but slowly returned to baseline concentrations by the end of the postprandial period. No differences were observed in plasma \( L-[\text{ring}-2\text{H}_5]Phe \) enrichments between treatments.

Whole-body protein kinetics

Whole-body protein kinetics over time are presented in Figure 4. Total Phe \( R_a \) (Figure 4A) equaled the rate of exogenous Phe \( R_a \) (Figure 4B) and endogenous Phe \( R_a \) (Figure 4C). The consumption of the labeled beef resulted in a rapid rise in exogenous Phe \( R_a \), with higher (peak) values observed between 60 and 180 min for minced beef than beef steak (\( P = 0.03 \)). Total exogenous Phe appearance, which was expressed as the AUC over the 6-h postprandial period, was calculated as the fraction of the total amount of Phe that was ingested (Equation 4). The fraction of dietary Phe that appeared in the systemic circulation during the 6-h postprandial period was 61 \( \pm \) 3% and 49 \( \pm \) 3% after minced beef and beef steak consumption, respectively (\( P < 0.01 \)). Endogenous Phe \( R_a \) decreased after beef consumption and did not differ between treatments. Total Phe \( R_d \) (Figure 4D) equaled the Phe-to-Tyr conversion rate, which was the first step in Phe oxidation (Figure 4E), and the utilization for protein synthesis (Figure 4F). Phe-to-Tyr conversion rates directly increased after beef consumption in both treatments and returned to baseline values by the end of the 6-h postprandial period. No differences were observed between treatments. Phe used for whole-body protein synthesis increased after beef consumption.
in both treatments with higher values observed between 60 and 90 min for minced beef than beef steak ($P = 0.02$).

Whole-body protein synthesis, breakdown, oxidation, and net balance in the basal and postprandial period are presented in Figure 5. Whole-body protein synthesis was expressed as the AUC of the Phe-utilization rate for protein synthesis (Figure 4F). No differences were observed for whole-body protein synthesis, although there was a trend for greater protein synthesis after beef consumption compared with basal values ($P = 0.08$). Phe released into the circulation from whole-body protein breakdown, which was expressed as the AUC of endogenous Phe Ra (Figure 4C), was lower after beef consumption compared with basal values ($P < 0.01$). No differences were observed between treatments. Whole-body protein oxidation, which was expressed as the AUC of the Phe-to-Tyr conversion rate (Figure 4E), was higher after beef consumption compared with basal values ($P < 0.01$). No differences were observed between treatments. The whole-body net protein balance equaled the synthesis minus breakdown. The net protein balance was higher after beef consumption than basal values ($P < 0.01$), with a more positive net protein balance observed after minced beef than beef steak consumption ($P < 0.01$).

Muscle tracer analysis and calculations

Mixed muscle protein–bound L-[ring-2H5]Phe enrichments and FSR values are presented in Table 1. One subject experienced the muscle biopsy procedure as highly unpleasant and continued the experiment without it, and as such, muscle data are presented for $n = 9$. Basal FSR values did not differ between treatments and are presented as the group average for both treatments. No differences were observed between treatments or between basal and postprandial FSR.

DISCUSSION

In the current study, intrinsically L-[1-13C]Phe–labeled beef was ingested, in combination with a continuous intravenous infusion of L-[ring-2H5]Phe and L-[ring-2H2]Tyr, to assess
postprandial protein kinetics after minced beef or beef steak consumption in older men.

Meat texture plays a major role in chewing efficiency and bolus formation during mastication (15). In agreement, it took our subjects more time and effort to consume the beef steak than minced beef. The postprandial measuring period was started after the complete consumption of the meat meal and may explain why the postprandial increases in plasma insulin (Figure 1) and EAA (Figure 2) concentrations after beef consumption did not differ substantially between treatments. However, because we applied intrinsically L-[1-13C]Phe-enriched meat, we were able to assess the specific release of meat-derived Phe into the circulation. In accordance, we observed a rapid rise in plasma L-[1-13C]Phe enrichment after meat ingestion (Figure 3A). The average plasma L-[1-13C]Phe enrichment showed a greater increase after consumption of minced beef than beef steak. In agreement, the subsequent calculation of meat-derived Phe appearance rates showed a more rapid digestion and absorption of meat protein after consumption of minced beef than beef steak (Figure 4B). The latter finding clearly shows that meat texture can modulate postprandial protein digestion and absorption kinetics in older men.

It has previously been suggested that the consumption of more rapidly digestible protein results in a greater stimulation of postprandial protein retention in older adults than does the consumption of a more slowly digestible protein (12, 13, 28, 29). This concept had been developed by assessing the digestion and absorption kinetics of whey (fast) compared with casein (slow) protein (30). However, because these proteins differ in both digestion and absorption kinetics as well as in amino acid composition, we revisited this concept by establishing differences in digestion and absorption kinetics after the ingestion of intact casein compared with hydrolyzed casein (9, 14). In line with our previous work, we observed a more-rapid protein digestion and absorption after ingestion of minced beef than beef steak, as evidenced by a more rapid postprandial rise in circulating exogenous Phe (Figure 4B). Furthermore, the observation of a more rapid protein digestion and absorption after ingestion of minced beef than beef steak also resulted in differences in digestion and absorption efficiency between minced beef and beef steak. Because we applied the use of intrinsically L-[1-13C]Phe-labeled beef combined with continuous intravenous infusion of L-[ring-2H3]Phe and L-[ring-2H2]Tyr, we were able to determine the fraction of meat-derived Phe that appeared in the circulation.
FIGURE 5. Mean (+SEM) whole-body protein metabolism expressed as the AUC (µmol Phe/kg) after consumption of minced or steak in older adults (n = 10). Data were analyzed with a 2-factor repeated-measures ANOVA with time (basal or postprandial) and treatment (minced or steak) as within-subject factors. Synthesis: time effect, P = 0.08; treatment effect, P = 0.20; time × treatment interaction, P = 0.38. Breakdown: time effect, P < 0.01; treatment effect, P = 0.55; time × treatment interaction, P = 0.34. Oxidation: time effect, P < 0.01; treatment effect, P = 0.66; time × treatment interaction, P = 0.28. Net balance: time effect, P < 0.01; treatment effect, P < 0.05; time × treatment interaction, P < 0.01. Postprandially significantly different than basal, P < 0.01; *minced significantly different than steak, P < 0.01. minced, minced beef; steak, beef steak.

during the postprandial period (Equation 4). As a result, we show that more meat-derived Phe became available after minced beef than beef steak consumption (61 ± 3% compared with 49 ± 3%, respectively) during the 6-h postprandial period.

It has been well established that the consumption of a meal-like amount of dietary protein increases protein synthesis and inhibits protein breakdown, which results in a (more) positive net protein balance during the postprandial phase (11). In agreement, the consumption of 135 g beef was shown to do the same (Figure 5). However, the postprandial protein balance was more positive after the consumption of minced beef than beef steak. This finding seems to be the result of small but consistent differences in whole-body protein synthesis and breakdown rates between treatments and were likely attributed to the more rapid digestion and absorption kinetics and subsequent greater plasma availability of minced beef–derived amino acids. In support, previous work has shown that meat protein utilization for protein synthesis is reduced when chewing efficiency is impaired in elderly subjects (31). Taken together, we conclude that minced beef consumption is more effective than beef steak consumption to augment postprandial protein retention in elderly men.

Skeletal muscle protein synthesis is highly responsive to food intake (6). However, the muscle protein synthetic response to food intake has been shown to be impaired in the older population (2-4). This anabolic resistance of aging is now believed to contribute to the progressive loss of muscle mass with aging. In the current study, we did not observe a significant increase in muscle protein FSR above baseline values during the 6-h period after the consumption of 135 g minced beef or beef steak (~26 g protein) in our elderly subjects (Table 1). However, because postprandial muscle protein synthesis rates generally peak at 1–2 h after food intake (32–34), it is possible that a temporary rise in muscle protein synthesis rates has remained undetected in the current study.

In retrospect, the absence of a substantial postprandial muscle protein synthetic response assessed over a 6-h period after the ingestion of 135 g beef may be less surprising when the fact that the postprandial rise in circulating plasma Leu concentrations plays a key-role in regulating muscle protein synthesis is considered (9, 35, 36). We observed an attenuated rise in plasma Leu concentrations after beef ingestion (Figure 2B) compared with previously reported responses after ingestion of similar amounts of casein or whey protein (7, 9, 14). After beef ingestion, it took ~2 h for plasma Leu concentrations to reach 234 ± 14 µmol/L. This amount is considerably less than peak plasma Leu concentrations that tend to be >500 µmol/L within 60 min after ingestion of 35 g whey protein (~4 g Leu) (7) or a Leu-enriched EAA supplement (~3 g Leu) (37). Research is warranted to compare protein digestion and absorption kinetics and subsequent postprandial muscle protein synthesis rates after the ingestion of the various dietary protein sources. Furthermore, our data seemed to suggest that greater doses of beef protein are necessary to augment postprandial muscle protein synthesis rates (38), or that additional protein sources should be ingested within a single meal to stimulate muscle protein synthesis in the older adult.

In conclusion, the consumption of minced beef is followed by a more-rapid protein digestion and amino acid absorption than the consumption of beef steak, which results in increased amino acid availability and greater postprandial protein retention in older men. Future clinical trials are warranted to evaluate the clinical relevance of food texture and proper mastication in muscle-mass maintenance for the older population.

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