Abstract Rationale: Marijuana and alcohol, when used separately and in combination, contribute to automobile accidents and failed sobriety tests of standing balance. However, the extent to which the drugs have additive effects on both of these measures is unknown. Objectives: This study was designed to compare directly the separate and combined effects of marijuana and alcohol on simulated emergency braking and dynamic posturography. Methods: Twelve healthy subjects who regularly used both marijuana and alcohol completed nine test sessions in a counterbalanced within-subject design. Subjects drank a beverage (0, 0.25, or 0.5 g/kg alcohol) then smoked a cigarette (0, 1.75, or 3.33% THC). Testing began 2 min after smoking and was conducted within the ascending limb of the blood alcohol curve. Results: The 0.5 g/kg alcohol dose significantly increased brake latency without affecting body sway. In contrast, the 3.3% THC dose increased body sway but did not affect brake latency. There were no additive drug effects on mood or behavior. Conclusions: Although field sobriety tests are often used to determine driving impairment, these results suggest that impaired balance following marijuana use may not coincide with slowed reaction time. Conversely, braking impairment from low doses of alcohol may not be revealed by tests of balance.

Keywords Marijuana · Alcohol · Equilibrium · Automobile driving · Psychomotor performance · Humans

Introduction

Many marijuana users simultaneously use other drugs. Alcohol is the drug most frequently paired with marijuanana (Earleywine and Newcomb 1997). Compared to their use of alcohol alone, combined use of marijuana and alcohol by college students has been more associated with increased substance use problems (Shillington and Clapp 2001). As alcohol is also the drug most commonly associated with vehicular crashes (Lowenstein and Koziol-McLain 2001), marijuana-alcohol combinations may represent an increased danger to a driver. Several behavioral tests of marijuana-alcohol combinations have shown that although the individual effects of marijuana on performance may be minimal, the combined effects of tetrahydrocannabinol (THC) and alcohol on performance are additive (Chesher et al. 1976, 1977; Belgrave et al. 1979; Perez-Reyes et al. 1988; Chait and Perry 1994). As with the effects of alcohol alone, these additive effects may be more prominent in the ascending limb of the blood alcohol curve; in one study, THC began counteracting the effects of alcohol 100 minutes after drinking began (Chesher et al. 1977).

Previous studies in our laboratory have shown that the effects of alcohol on both body sway and a simulated driving emergency braking task are robust and reproducible in a dose-dependent manner (Liguori et al. 1999; Liguori and Robinson 2001). In addition, the effects of high-potency marijuana (3.95% Δ-9 THC) on these measures were found to be comparable to effects at a breath alcohol concentration (BrAC) of 0.05% (Liguori et al. 1998). If THC and alcohol have additive effects, the combined effects of moderate doses of these drugs should produce impairment similar to that from BrACs above 0.08%. Other researchers have reported driving impairment from the combination of low doses of THC and alcohol that had no or modest impairing effects when given by themselves (Robbe 1998; Ramaekers et al. 2000; Lamers and Ramaekers 2001). In one of these studies, combinations of THC and a BrAC of 0.04% produced driving impairments equivalent to impairments from BrACs of 0.09–0.14% (Ramaekers et al. 2000).

The purpose of this study was to determine if alcohol-induced impairment of body sway and simulated emergency braking would be significantly increased by mari-
We postulated that marijuana in combination with alcohol would produce greater impairment of both measures than alcohol alone. The study was designed to measure behavior within the ascending limb of the blood alcohol curve, when performance impairments are most likely (Nicholson et al. 1992). We also postulated that the subjective “high” from marijuana in combination with alcohol would exceed that of marijuana alone.

Materials and methods

Subjects

Twelve subjects (four female, eight male; one African-American, 11 Caucasian) between the ages of 21 and 45 years were recruited via newspaper advertisements and initially screened by telephone interview. For inclusion in the study, subjects were required to report: possession of a current driver’s license, body mass index (BMI) <30, use of marijuana between 2 and 21 of the past 30 days, not trying to stop or reduce caffeine, alcohol use, or caloric intake; no present use of prescription, over-the-counter, or illicit psychoactive medications, and no significant medical illness in the past 6 months. All subjects completed the Alcohol Use Disorders Identification Test (AUDIT) to screen for problem drinking (maximum allowable score=10; Saunders et al. 1993). So that present results could be compared with those of future sleep-related studies in our laboratory, subjects were also required to report time-in-bed between 7 and 9 h nightly, less than 2 h of variation in bedtime, sleep pattern devoid of naps, and no rotating shift work. Female subjects were excluded if they were pregnant, planning to become pregnant, or breast-feeding. Subjects who met all these criteria then met with a physician who conducted a physical examination and clinical interview to screen for medical conditions contraindicated for marijuana or alcohol use, past or current Axis I psychiatric disorder (DSM-IV criteria), and history of alcohol or non-nicotine drug abuse or dependence in the past year.

The mean (±SD) age of the subjects was 24±3 years, their mean body weight was 74±16 kg, and the mean BMI of the group was 24±4. Subjects reported smoking marijuana an average of 10 of the 30 days before giving informed consent (range 2–19 days) and average consumption of 12 standard alcohol drinks per week (range 4–24). Seven subjects (three female, four male) were current smokers of tobacco cigarettes (mean eight cigarettes per day, range 1–20 cigarettes). Two women reported use of oral contraceptives.

General procedure

The experimental protocol was approved by the Institutional Review Board of Wake Forest University School of Medicine. Subjects completed one practice session and nine test sessions. During practice sessions, subjects completed all tasks and forms without receiving drug. Subsequently, subjects were transported to and from the laboratory by taxi service for all test sessions. Test sessions began between 1215 and 1745 hours and were separated by a mean of 7 days (range 2–28 days). Participants were instructed to abstain from marijuana for 48 h, alcohol and caffeine for 12 h, food for 4 h, and tobacco cigarettes for 1 h before each test session.

Upon arrival in the laboratory, subjects provided a urine sample that was used for qualitative illicit drug content analysis [Triage panel plus TCA (tricyclic antidepressants); Biosite, San Diego, Calif., USA] and, in women, pregnancy testing (QuickVue; Quidel Corp., San Diego, Calif., USA). After heart rate, blood pressure, BrAC, and carbon monoxide (CO) level were measured, subjects completed a field sobriety test (standing balance with eyes closed, walk-and-turn, one-legged balance, finger-to-nose, and alphabet recitation) and visual analog scales (see below).

In each test session, subjects received a different pairing of alcohol dose (0, 0.25, and 0.5 g/kg) and ∆-9 THC dose (0, 1.75%, and 3.33%). A test battery was scheduled to coincide with both the ascending limb of the blood alcohol curve and peak THC absorption (see Fig. 1). Subjects drank the beverage within 15 min, rested for 10 min, then smoked a single cigarette within 6 min. Testing began 2 min later and typically concluded 65 min after drinking began. Subjects then rested for 2 h 45 min, during which they were provided a lunch and, in tobacco smokers, ad libitum access to their cigarettes. BP, HR, and BrAC were measured at 30-min intervals to monitor subject safety. At the end of the rest period, subjects were required to complete a field sobriety test with no evidence of impairment before being taken home by taxi service.

Alcohol administration

Each active alcohol dose (0.25 or 0.5 g/kg) was prepared as a combination of diet tonic water and alcohol (95% w/v) for a total volume of 795 ml. Placebo beverages consisted of 795 ml of diet tonic water. During each test session, the 795 ml beverage was divided into three 265 ml drinks, and 4 ml of lime juice was added to each drink. To provide olfactory and taste cues, 1 ml of alcohol was added to each of the three drinks during placebo sessions. Subjects received a beverage at 5-min intervals. Drinking was monitored so that the three drinks were consumed at an even pace over a 15-min period.

Marijuana administration

Marijuana was administered in cigarettes prepared and supplied by the National Institute on Drug Abuse. The cigarettes averaged 85 mm in length and 25 mm in circumference and contained 0.003%, 1.75%, or 3.33% THC. Cigarettes were stored in airtight containers in a freezer and humidified overnight before test sessions. Each subject smoked the cigarette according to a uniform puffing procedure slightly modified from that previously reported (Higgins and Stitzer 1986). The following cycle was repeated through ten inhalations and exhalations: inhale for 7 s with ad libitum puff volume (Block et al. 1998), retain smoke in lungs for 7 s, exhale, inhale 30 s after prior inhalation ended.